



Public Health Engineering In Precarious Situations



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Manual intended for the setting up of public health programmes in disadvantaged areas, particularly in refugee and displaced persons camps, and in health structures.

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Foreword

This handbook is a collective accomplishment of the different sections of Médecins Sans Frontières (MSF), and has been written to consolidate the broad experience of MSF in the field of public health engineering. The first edition of this book was written in 1994 and is presently updated with a second edition.

Public health engineering, long considered a specialist field by medical organizations, is not an end in itself. It has a direct influence on several major diseases related to poor water supply, hygiene and/or sanitation, like Chagas, Dengue, Diarrhoea, Guinea Worm, Malaria, Plague, Trachoma, Trypanosomiasis, Typhus, Viral Haemorrhagic Fevers or Yellow Fever. It is important to consider water supply, sanitation and hygiene not simply in terms of technical activities, but as an integral part of medical programs, in the same way as other preventive health work like vaccination, mother and child care and home visiting.

The techniques described in this guide were chosen for their simplicity of implementation and maintenance, and because they are financially affordable. It is a handbook supporting the implementation of health programmes in deprived environments, in particular in closed settings like refugees and displaced persons camps, and in health structures. The purpose of the book is to increase the effectiveness with which relief workers can provide sound water, hygiene and sanitation assistance in precarious situations. To achieve this, the book provides pragmatic information to the field worker with a minimum of theoretical background.

Nevertheless, it should always be borne in mind that, however good the techniques are in theory, it is only when they are correctly applied that they can have any health impact. However important it is to produce appropriate technical solutions, they have to be socially acceptable. The necessity for complementary activities such as health promotion and training of local technicians can never be too highly emphasized.

The infrastructures described in this manual aim to improve the living conditions of populations in need and to reduce mortality and morbidity of affected populations. Paradoxically, fatal accidents can occur during the construction and/or the use of these infrastructures. Diggers can suffocate by natural gasses during excavation of dire needed wells. People can be crushed during collapse of inappropriate deep latrines. As such, the users of this manual are urged to take the provided security recommendations at heart to avoid human dramas.

In addition to technical knowledge, the work of the "sanitarian" demands a good knowledge of the population being worked with, and of local hygiene practices. Some teaching skills and a sense of humour are also of great help.

Using this guide

The guide starts with an introductory chapter (Chapter 1, "Management of Water, Hygiene and Sanitation Activities") covering the fundamentals of assessments and situation analysis, strategy definition and planning, implementation, monitoring and evaluation of projects.

Chapter 2, "Water Supply", covers several aspects of water supply in precarious situations: water related diseases, required quantities based on basic human water needs, quality related to the characteristics of water, accessibility, different types of water resources with their protection and operation, water treatment methods, and distribution including transport and storage.

Chapters 3 to 8 cover the different aspects of sanitation in precarious situations: "Safe Excreta Disposal" (Chapter 3), "Disposal of Runoff Water and Wastewater" (Chapter 4), "Collection and Disposal of Refuse" (Chapter 5), "Medical Waste Management" (Chapter 6), "Vector Control" (Chapter 7) and "Disposing of Dead Bodies" (Chapter 8).

All the chapters of the guide are presented in a similar way. They start with a narrative section answering several questions according to the following sequence: *Why*, *What*, *Where*, *When* and by *Who*, and finally *How*. Each narrative section ends with a list of information sources (Further reading) that can be consulted if more information is required. Following each narrative section, practical Technical Briefs (T.B.) are presented, describing different techniques commonly used in the field.

At the end, there is a glossary giving an as clear as possible definition of the technical terms used in this guide, or of those that are used every day in this domain. A conversion table, allowing to pass from the US / Imperial units system to the metric units system (and vice-versa), and formulas are also included.

This guide was designed as an user's manual. The authors strongly advise the user first to read it completely to have a good overview of what can be the water, hygiene and sanitation problematic in deprived environments, and then to utilize the needed issues, under the form of the Technical Briefs.

Criticism and comments from users of this guide are welcomed. They are important to ensure that the guide is answering as appropriate as possible to the realities and needs of the field. Please send your comments to your technical Water, Hygiene and Sanitation referents.

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Chapter 1

1.1 Why are water, hygiene and sanitation activities important?

Humanitarian aid organisations are confronted daily with the deadly consequences of war, violence, natural catastrophes, poverty and illness. The typical contexts where the humanitarian aid has to intervene favour the spread of infectious diseases. In emergency situations, people are even more at risk of infection, linked to a weaker health condition and to exposure to new pathogens (lack of immunity to a disease or a particular strain of the disease in the settlement area). People are also more exposed to contextual risk factors including poor housing and extreme weather conditions, poor water, hygiene and/or sanitation conditions, population density, deterioration of health services and lack of access to effective treatment, physical (injuries) as well as socio-economical insecurity. Furthermore, people's immunity can be weakened due to multiple infections and malnutrition.

Diarrhoeal disorders kill millions of people each year, almost all of them in low-income countries, the vast majority children under five. Malaria is a major cause of morbidity and mortality in many parts of the world. Other diseases related to poor water supply, hygiene and/or sanitation (e.g. Chagas, Guinea Worm, Lassa Fever, Plague, Trachoma, Trypanosomiasis, Typhus, Yellow Fever) remain a major threat to millions in low income countries, particularly for those who are displaced or otherwise affected by conflicts and disasters.

Providing in these precarious situations the basic supply of water, hygiene and sanitation (WHS) has a direct and documented impact on infectious diseases and should be included in the framework of the medical strategies. Their objective is to contribute to the reduction of morbidity and mortality. It is therefore important to consider water, hygiene and sanitation activities not simply in terms of technical programmes, but as an integral part of medical programmes, in the same way as other preventive work like vaccination, mother and child care and home visiting. Having access in these precarious situations to decent sanitation facilities also adds to the protection of human dignity.

1.2 What are water, hygiene and sanitation activities?

Water, hygiene or sanitation activities aim to reduce the environmental disease reservoirs and interrupt the transmission routes. Depending on the context, it means improving environmental hygiene and health by increased access to an adequate drinking water supply, a proper excreta disposal, runoff and waste water disposal, collection and disposal of refuse and medical waste, effective vector control interventions and proper disposal of dead bodies.

WHS interventions, integrated within a more global medical project should be set up following the different stages of the project cycle. For a maximum health impact, attention should be given to the "technical aspect" as well as to the "human behavioural and cultural related aspect". However good the techniques are, it is only when they are correctly used and maintained that they can have any prolonged impact on health. At the opposite, good health promotion programs cannot function without good quality infrastructures. WHS interventions have to answer to health problems but also to the beneficiaries needs.

1.3 Where/when should water, hygiene and sanitation activities be implemented and by who?

Water, hygiene and sanitation activities must be implemented in Health structures: this is to enable curative interventions and to prevent patients from being infected with another disease while in the health structure, as well as preventing health workers, visitors and neighbours from getting injured or infected. These WHS measures taken in the health structure consist of the Essential Requirements (T.B. 1.08) with regards to the provision of sufficient potable water, the provision of adequate excreta disposal, waste water, medical waste management and vector control. Furthermore, infection control measures must be respected and applied by all staff according to the universal / standard precautions.

Water, hygiene and sanitation activities must also be implemented in case of humanitarian crises to prevent an increase of morbidity and mortality in the affected population. In acute humanitarian crises,

the implementation of preventative water, hygiene and sanitation activities is mandatory. In chronic humanitarian crises (e.g. repetitive outbreaks of cholera, malaria and other infectious diseases) appropriate water, hygiene and sanitation activities must complement the other medical strategies to reduce and ultimately stop the spread of the disease by blocking the routes of transmission.

The most appropriate water, hygiene and sanitation (WHS) implementation strategy will vary from place to place and over time, and has to be established in close co-operation with the whole coordination team and in close collaboration with the respective authorities. The involvement and close collaboration of both medical and non-medical staff are essential for the successful implementation of any WHS strategy. In case responsibilities are clear, this multidisciplinary approach increases largely the quality and impact of the projects.

1.4 How should water, hygiene and sanitation activities be managed?

The project cycle allows prioritizing interventions, understanding how to establish them and to follow up their evolution. It is important to analyse and define the real problems first and then to fix and define the global objective, the specific objective(s) and the results that have to be reached during the life of the project, the activities to implement and the means needed. Tools that help this process are the problems and objectives trees, and the logic framework (section 1.5 Further Reading).

1.4.1 Assessment and analysis

According to the level of emergency, perform a rapid assessment (1 or 2 days) for an acute emergency, or a rapid and then a more in-depth assessment (from a few days to a few weeks) in case of chronic emergencies and stabilized situations.

The assessment phase allows the collection of:

- population data (e.g. target population, hygiene practices).
- health data, in collaboration with medical teams (e.g. mortality and morbidity figures, weekly cholera incidence rates).
- technical data (e.g. number of latrines, turbidity).
- physical environmental data (e.g. monthly average rainfalls, high water table).
- socio-political data (e.g. security, upcoming elections).

There are a variety of methods and associated tools to collect water, hygiene and sanitation related data to complement the medical information. Data collections tools for assessments are described in T.B. 1.01.

The environment must be studied and described. A map, even basic must be established to visualize the global situation as well as the existing water, hygiene and sanitation facilities (T.B. 1.02). An area sampling (T.B. 1.03) can also be organized to evaluate the global size of the population of concern as well as the high and low population density areas within a camp.

The checklists presented in this chapter help to target the required information and to prepare data collection methods that will be used during assessments:

- from a general point of view, in the case of a health structure (T.B. 1.04).
- from a general point of view, in the case of a refugee or displaced persons camp (T.B. 1.05).
- from the more specific water, hygiene and sanitation point of view (T.B. 1.06; 1.07).

Even if these checklists help to target the information needed, they must however not be considered as a limit in the type of information and in the way to collect them. One must be aware that bias can exist in the information collected, specially if only interviews are used. A double crosscheck of the information should thus be undertaken.

Once collected, those data must be analysed, notably by comparison with indicators like the Essential Requirements (T.B. 1.08, 1.09), and be used in all the remaining steps of the project cycle.

1.4.2 Strategy planning

On the basis of the assessment and analysis, the strategy planning can be initiated. A global objective must first be established. From there, specific objectives and results that have to be reached must be defined. Activities to obtain each of these results must be determined. During this phase, human and logistic needs allowing to put the activities in place must also be defined.

Finally, a detailed budget must be joined to all proposals of intervention. This budget must be designed on the basis of the human and logistic needs and of a chronogram of intervention.

From a general point of view and during all the duration of the project, it is extremely important to maintain and/or to reinforce the links with the population and other actors, like institutions, traditional social groups and/or other aid-agencies.

1.4.3 Implementation

The essence of the intervention lies in the tangible realisations and not in never-ending assessments and planning. The period between the initial assessment (exploratory phase) and the first actions in an acute emergency can be very short. The extreme seriousness of some situations (e.g. starvation, conflicts, population displacement) requires a quick start-up with tangible realisations. It is not compulsory to obtain all the means desired before starting up an intervention. Every action aiming to rapidly improve the living conditions of an at-risk population is welcome.

For chronic emergencies and stabilized situations, the period covering the initial assessment to the implementation phase can be longer because of the in-depth assessment and the longer strategy planning phase.

Training modules for the staff should come with the start-up of the activities to be able to guarantee their quality and their success. Every member of the team should know his responsibilities and must have access to the information and the tools needed to achieve the tasks he is responsible for.

1.4.4 Monitoring

The objective of monitoring is to guarantee the permanent appropriateness between the objectives, the means implemented, the expected results and the results reached in the frame of the chronogram of the intervention. Monitoring is the regular observation and recording of activities taking place in a project. It is a process of routinely gathering information on all aspects of the project. Here again, activity reports, financial updates and permanent communication between the medical and logistical teams allowing to present epidemiological data and related improvements are of utmost importance. It is a very dynamic phase generating several questions, but also proposing alternative solutions allowing an increase in the performances. It requires a lot of flexibility to accept to modify point of views or decisions no longer considered as pertinent, and also a lot of energy to be able to locate the elements blocking the project.

In the context of these guidelines dedicated to water, hygiene and sanitation, data collection methods (T.B. 1.01) can also be used as a monitoring tool. The different checklists presented in this chapter (T.B. 1.04 to 1.07) can also be used to prepare the monitoring tools; by comparison between the data collected based on the checklists during the assessment phase and during the implementation, improvements in the water, hygiene and sanitation situation can be detected.

1.4.5 Evaluation

Evaluating a project is to look at its real impact (e.g. morbidity and mortality reduction) and at the results of the activities. It is also to evaluate if the global and specific objectives and their specific activities (e.g. WHS activities) are reached. The evaluation allows to highlight the strengths and the weaknesses of the project and to correct the situation if needed. An evaluation can be done at any time during the life of the project and is essential to allow improvements to occur and (potentially) a redefinition of the specific objectives that have to be reached during an extension of the project.

1.5 Further reading

A.M. Almedom, U. Blumenthal, L. Manderson

Hygiene Evaluation Procedures – approaches and methods for assessing water and sanitation related hygiene practices.

INFDC / London School of Hygiene and Tropical Medicine. London, 1997.

A.S. Benenson (Editor)

Control of Communicable Diseases Manual

American Public Health Association, 1995

V. Curtis, B. Kanki

A manual on hygiene promotion

UNICEF / London School of Hygiene and Tropical Medicine. London, 1999.

S. Ferron, J. Morgan, M. O'Reilly

Hygiene Promotion. A practical manual for relief and development.

ITDG Publishing. Care International. London, 2000.

R. Sawyer, M. Simpson-Hébert, S. Wood

PHAST Step-by-step Guide: a participatory approach for the control of diarrhoeal disease

World Health Organisation, 2000

T.B. 1.01 Data collection methods

Water, hygiene and sanitation activities are integrated in medical projects which are based on the actual medical needs. There are a variety of methods and associated tools to collect water, hygiene and sanitation related data to complement the medical information.

Procedure

- Familiarise yourself and the data collection team with the methods, prior to use. Use the methods that the data collection team and the participants feel most comfortable with.
- Introduce yourself, the team and the data collection method to be used to the beneficiaries.
- Do the assessments by using all your senses.
- Make good records immediately.
- Be unobtrusive and considerate in your approach. Practitioners should be sensitive to the cultural and social context and not raise unrealistic expectations from the beneficiaries.
- Cross check the translator's performance and neutrality with another translator.
- Ensure that data is also collected from the more vulnerable groups of society.
- Respect informant confidentiality and security; data collection should have the consent of the community.
- Divide beneficial groups into sub-groups according to gender or age, when appropriate.
- Stimulate the data collection activity, but without "leading" the participants into a particular response or direction.
- Analyse all collected data. Therefore should only relevant information be collected.

Remarks

- An initial assessment should always be made, even in an acute emergency. The initial assessment is also important as the basis to prepare the in-depth assessment during chronic emergencies and stabilized situations.
- The tables hereunder present the data collection tools that can be used for rapid initial sanitary assessments (Table 1) and for in-depth sanitary assessments. In the latter case, two kinds of methods can be considered: the classic methods (Table 2) and the participatory methods (Table 3).
- Once collected, those data must be analyzed. Results of these analysis must be used to define the strategy and to plan the project.
- All the methods presented hereunder can also be used for assessments outside the water, hygiene and sanitation field.
- The participatory approach has the advantage to be in closer proximity with the beneficiaries, and the discussions they have amongst themselves make that they learn from each other, besides just data collection. The inconvenience however is that the exercises the participants are asked to perform, do take a lot of time. When time is limited, the classic approach is more suited for the in-depth assessment.
- More assessment methods exist and can be found in more specialized literature (section 1.5 Further Reading).

Table 1: Data collection methods for initial assessments

Name	Description	Purpose	Material / Tools
Desk based literature review	Reading of relevant information that is already available in: -documents (e.g. medical, water, hygiene and sanitation). -medical data sheets. -books / guidelines / manuals	-To gain an insight of the situation before the assessment on the field is started (this review can already start in the headquarters or on the way to the study site).	-Reports (e.g. minutes of meetings, streps) -Medical data sheets -Books / guidelines -Media (e.g. newspapers)
Key-informant interview	Interviewing informally anyone who can provide detailed information, on the basis of his special expertise or knowledge of a particular issue: e.g. village leader, local health worker, hospital director, head nurse, entomologist. <i>NB: Women (and children) can often be key-informants in water, hygiene and sanitation matters.</i>	-To gain a good overview of the relevant (water and sanitation) issues. -To feed the potential in-depth assessment. -To identify issues to cover / validate in (structured) observations.	-List of topics to cover (based on checklists) -Basic survey form -Notebook and pencil
Mapping and area sampling (T.B. 1.02 and 1.03)	Drawing of a map of the study site, showing places or features that are important for the project: e.g. water sources, defecation areas, roads / buildings. Area sampling permits a good estimation of the population number, the household size and the average available space per person.	-Different maps can be made of the area and used for orientation and planning purposes. -The estimation of the population living in a closed setting helps to determine important data such as Crude Mortality Rate, the quantity needed for water and latrines. -To feed the potential in-depth assessment.	-Compass / GPS -Long tape measure -Hand clicker -Note book and pencil -Graph paper -Ruler -Calculator -Rope
Health walk	A walk through the study site(s) in a meandering fashion, to gather information through (unstructured) observations and informal talks with the population. <i>NB: Most effective when carried out at dawn or dusk, when most hygiene practices and water collection occur.</i>	-To familiarise yourself with the physical context in which hygiene practices occur. -To investigate how people behave in their daily routines -To feed the potential in-depth assessment.	-List of topics to cover (based on checklists) -Map if available -Basic survey form -Note book and pencil
Spot-check observation	Record information (defined on a clear but short list of topics) during the first moment of observation (e.g. quick observation of the issues on the spot-check list when entering a dwelling / hospital service or ward). <i>NB: A rapid method particularly useful when time is a major constraint.</i>	-To investigate the presence or absence of some clearly defined hygiene / health behaviour and practices -To feed the potential in-depth assessment.	-Spot-check list (based on previous data collection / checklists) -Basic survey form -Note book and pencil

Table 2: Classic data collection methods for in-depth assessments

Name	Description	Purpose	Material / Tools
Desk based literature review	Reading of relevant information that is already available in: -documents (e.g. medical, water, hygiene and sanitation). -medical data sheets. -books / guidelines / manuals.	-To gain an insight of the situation before the assessment is taken back to the field again (this review can already be done at the office).	-Reports (e.g. minutes of meetings) -Medical data sheets -Books / guidelines -Information collected during the initial assessment
Structured observation	(Continuous) observation to collect information defined on a clear but short list of topics: e.g. - Continuous structured observation (e.g. each time an action listed on the observation sheet is done, it is marked on the sheet). - Ticketing (e.g. each time a person collects water, a mark is put on the ticketing sheet).	-To see where water and sanitation-related facilities are located. -To obtain information on water, hygiene and sanitation issues and practices in and around these facilities, at people's homes or in their working environment, in health structures.	-Observation checklist (based on previous data collection / checklists) -Ticketing schedule -Pencil
Structured interview	Interviewing people based on a questionnaire with closed ended questions on predetermined topics (e.g. the answer can only be yes or no, or an option within a multiple choice question).	-To collect mainly factual and quantitative data (data is relatively easy to collect and to interpret as it is a preconceived questionnaire, which on the other hand is difficult to prepare).	-Written interview with closed questions on predetermined topics (based on previous data collection / checklists) -Pencil
Semi-structured interview	Interviewing people based on a questionnaire with open ended questions on predetermined topics (e.g. person being interviewed can answer with his own words). <i>NB: it is useful to have an assistant to take notes.</i>	-To investigate general as well as specific issues by asking questions, informally but systematically. -To investigate which hygiene / health practices are ideal / acceptable, and why. -Collection of qualitative data.	-Written interview with open ended questions on predetermined topics (based on previous data collection / checklists) -Notebook and pencil
Focus group discussion	Discuss a specific topic of interest to the investigator with a small group of people having similar backgrounds or experiences. <i>NB: it is necessary to be at least two for the focus group discussion: 1 moderator and 1 person taking notes.</i>	To investigate: -A range of opinions / points of views on the topic of interest. -The wide variety of local terms and expressions linked to the topic of interest. -The meanings of survey findings that cannot be explained (statistically).	-Written open ended questions and/or pictures to introduce the topic of interest -Notebook and pencil (and/or tape recorder)

Table 3: Participatory data collection methods for in-depth assessments

Name	Description	Purpose	Material / Tools
Community / Health structure mapping	The participants are asked to make a map of their community / health structure, showing places that are important for them (e.g. market place) and to include features of interest to the investigator (e.g. water sources, latrines).	-To find out what facilities related to health and hygiene exist and to which the community has access. -To find out about hygiene and sanitation resources in people's homes or health structures (e.g. latrines). -To find out how the community / health staff perceives its surrounding / working environment and what it prioritises within it.	-Blackboard and chalk or -Paper and markers
Three pile sorting	Participants have to discuss and decide if water, hygiene and sanitation related activities presented on the pictures are good, bad or in-between, and why. Once consensus is reached, the picture is placed in the appropriate good, in-between or bad pile. The discussions between the participants will provide essential information to the investigator.	-To break down social barriers and establish good communication. -To introduce potentially sensitive / personal topics (e.g. latrine use) that need to be investigated (knowledge / perception of the participants). -To choose improved hygiene behaviour, based on people's perceptions and needs.	-Sets of pictures showing water and sanitation related activities -Good, bad and in-between signs -Notebook and pen
Pocket chart	The participants can indicate individually and secretly which water, hygiene and sanitation resources / methods, depicted on a matrix, they are using. The discussions between the participants afterwards will provide essential information to the investigator on the actual water, hygiene and sanitation practices. <i>NB: each picture should be defined and its meaning agreed upon before a vote on a predefined aspect of the picture takes place.</i>	-To investigate which resource / method is actually used, for what purpose, or by which population group (e.g. investigation on defecation methods used).	-Sets of pictures showing water, hygiene and sanitation activities. -Voting cards -Pocket chart -Notebook and pen
Gender / Staff role task analysis	An investigation of gender / staff issues, particularly in relation to task allocation and resource management. Pictures on various water, hygiene and sanitation activities are passed around and the participants are asked about who is performing the different tasks. Once consensus is reached, the picture is placed in the appropriate man, woman or both / medical, non-medical or both pile. The discussions between the participants will provide essential information to the investigator.	-To find out which activities or tasks are acceptable for / assigned to men, women or both / medical staff, non-medical staff or both, and why.	-Sets of pictures showing relevant activities / tasks -Picture of a man, woman and both together / of medical, non-medical staff and both together -Notebook and pen

T.B. 1.02 Mapping

This assessment method consists of drawing a simple map of the study site by means of a compass or a GPS. This map can also show places or features that are important for the program in general or more specifically for the water, hygiene and sanitation activities. The map can also help in project orientation and planning purposes and is essential for area sampling.

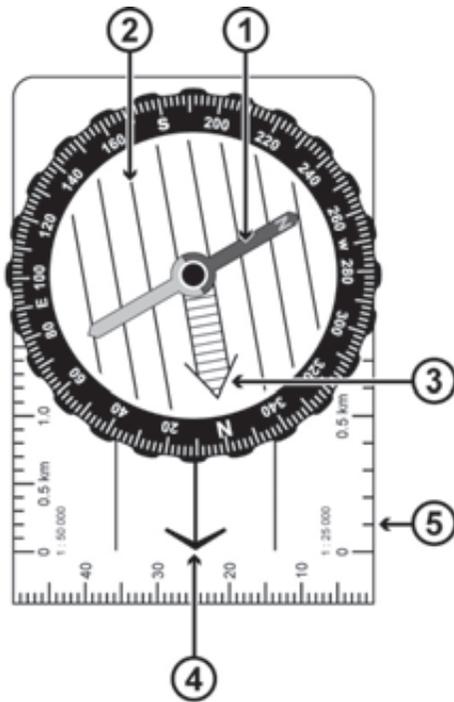
Procedure

Recording the landmarks

- Step in a normal pace along a preset length (e.g. 100 m) and count the number of footsteps needed to cover the distance. The average footstep can then be calculated by dividing the preset length by the number of footsteps: e.g. $100 \text{ m}/119 \text{ steps} = \text{average footstep of } 0.84 \text{ m}$.
- Go to a specific landmark at the outskirts of the site.
- Identify the north by means of the compass.
- Point the direction arrow towards the next landmark and rotate the graduation ring until the graduation ring arrow is in position with the magnetic needle indicating the north (0°).
- Note the bearing (degrees of the angle in between the direction of the second landmark and the north). The bearing can be read on the graduation ring at the position of the direction arrow.
- Start walking in a normal pace towards the next landmark and count the number of footsteps needed to arrive there. In order not to make mistakes during the counting of the footsteps, it is strongly recommended to use a hand clicker.
- Note the number of footsteps on the same line as the bearing.
- Keep on doing the same procedure from landmark to landmark until the starting point is reached again.

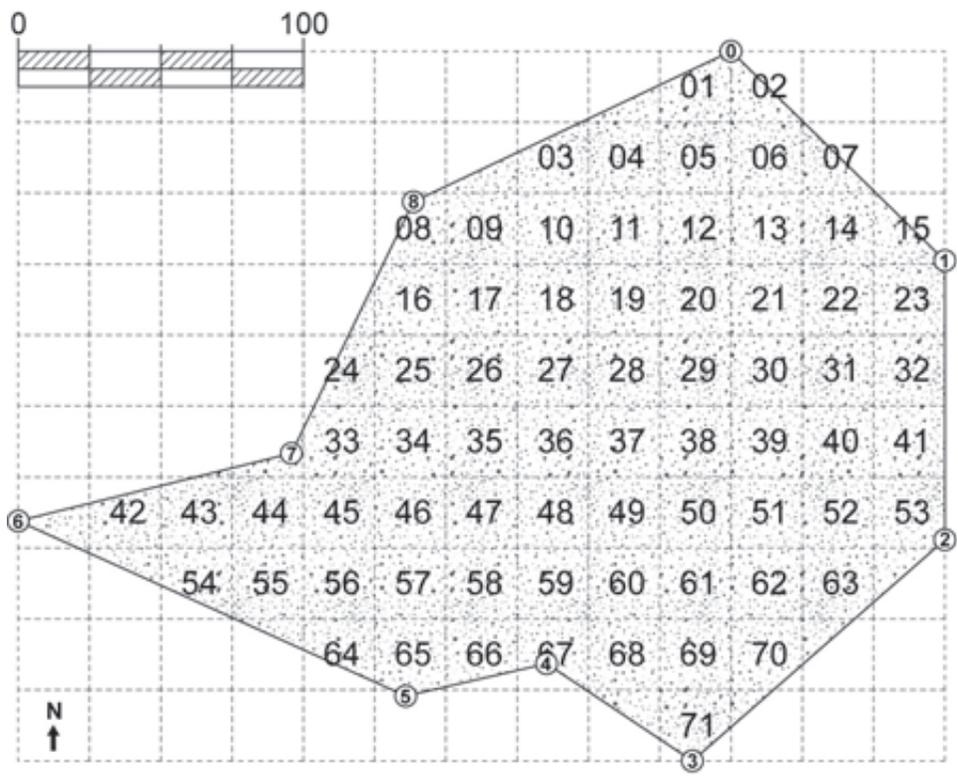
Drawing the map and calculating the total surface of the site

- Choose a place on a graph (millimetre) paper to plot the first landmark. This first mark should be chosen in order that all the other landmarks can be plotted on the same sheet, taking into account that the north should be on the top of the paper. It is also necessary to decide the scale of the map from the beginning.
- Rotate the graduation ring until the correct first bearing (measured during the landmark recording) is positioned exactly in front of the direction arrow.
- Put the preset compass with one of its long edges on top of the first designated landmark on the paper and turn it around this point until the graduation ring arrow points exactly towards the top of the paper, which is the north of the map (the parallel lines of the graduation ring should be exactly in position with the vertical lines of the graph paper).
- Draw a line on the graph paper starting from the first landmark following the direction arrow of the compass. Drawing the line in the opposite direction of the arrow will be an error that is dragged along in the remaining of the plotting, resulting in a faulty map.
- Convert the number of footsteps between the first and second landmark into the actual distance, which needs to be adapted for the map according to the chosen scale.
- Measure the up-to-scale length from the first mark along the drawn line and plot the second mark.
- Keep on doing the same procedure from landmark to landmark until the starting point on the map is reached again.
- Draw a grid on the map, using squares of 25 m by 25 m according to the map scale.
- Count and number the squares within the perimeter. Partial squares with at least half of their surface within the perimeter are calculated as whole ones, whereas those with less than half of their surface within the perimeter are ignored. It is estimated that the partial squares that have been included as whole ones compensate for the ignored partial squares. *The total number of squares considered to be within the perimeter of the figure equals 71.*
- Multiply the total numbers of squares (complete and accepted partial ones) with 625 m^2 (surface of a 25 m x 25 m square). This calculation will give an acceptable estimation of the total surface of the site. *For the figure, the total surface is estimated at $71 \times 625 \text{ m}^2 = 44,375 \text{ m}^2$ or 4.4375 ha .*

A**B****C**

Point	Degrees (°)	Meters
1	135	100
2	180	100
3	225	120
4	310	70
5	250	50
6	295	150
7	75	100
8	25	100

D



Key

Input

- A. Compass
- B. Hand clicker
- C. Recorded coordinates
- D. Finished map

1. Magnetic needle indicating north (red part)
2. Rotating graduation ring
3. Graduation ring arrow
4. Direction arrow
5. Long edge of the compass

- Compass or GPS (with software)
- Long measuring tape (e.g. 50 m)
- Hand clicker
- Notebook and pen / pencil
- Ruler
- Calculator
- Graph (millimetre) paper

Remarks

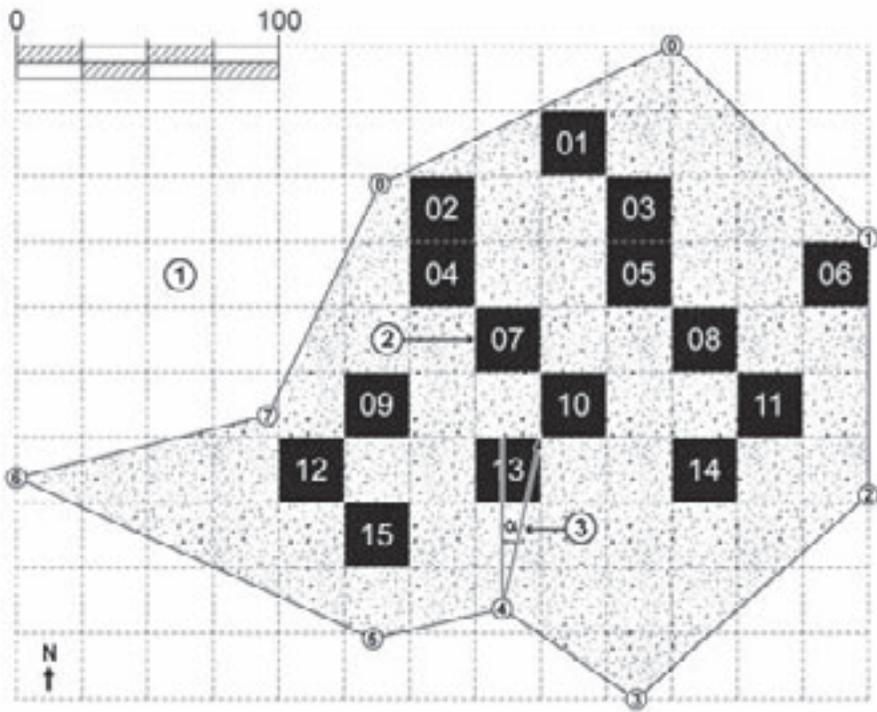
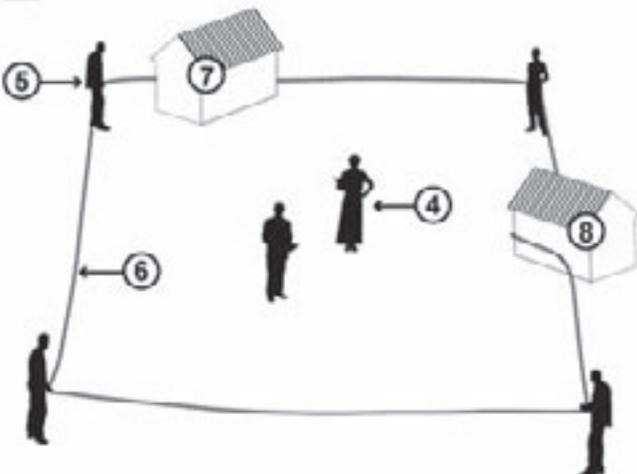
- The study site will be mostly a refugee / displaced persons camp or a health structure, but it could also be a village or even a sector of a town (e.g. slum area).
- Walk as much as possible in a normal pace in order to stick to the average footstep length. However, footsteps will vary in length when climbing / descending a steep slope or when the access of the terrain is difficult.
- All the landmarks should be more or less located around the external limits of the site. However, don't choose too many landmarks as this will increase the workload, not only to record them but also to draw the map. Obviously, the more landmarks are taken, the more the final map will resemble the reality of the field. But such precision is in most cases not necessary, and certainly not during acute emergencies.
- Be aware that the indication (precision) on the rotating graduation ring is often at 2 degrees interval.
- During the plotting of the landmarks of the map, the magnetic needle of the compass doesn't play any role anymore.
- Indicate the north on the map, as future users won't know which is the top of the paper.
- The scale of 1/10.000 is often chosen for a first map because 100 m on the field corresponds to 1 cm on the graph paper. This enables mostly to put the whole site on one A4 sheet, which is sufficient for the first usages of the map. It is important that the scale is indicated directly on the map.
- When the last line, plotted according the measured bearing and up to scale length, ends a long way from the first landmark on the drawn map, it indicates that something went wrong during the mapping. All marks should be verified according to their up-to-scale length and their bearing. A common mistake is that a line is drawn in the opposite direction of what it should be (180° off). Once this has happened, the map can't be correct anymore. If after thorough verification and potential re-plotting of the whole map, the final mark still doesn't correspond at all with the first mark, it's probable that something went wrong during the recording of the landmarks on the field.
- Small discrepancies in between the final and the first mark are common and mostly due to small inaccuracies during the recording of the landmarks and the plotting of the map. These aren't worrying because the mapping technique can only provide a sketch of the actual situation on the field anyway.
- The simple map of a camp will often be used as a basis for area sampling (T.B. 1.03). The initial map or a more precise version with more landmarks in a later stage can also be used to indicate specific places (e.g. river, wells) and facilities (e.g. latrines, health centre) that are important for the overall program. These indications can be directly drawn on the map, but a legend should be added on the paper to explain the symbols used.
- Instead of using a compass, the mapping can also be done by means of a GPS (Global Positioning System). Each time a landmark is passed, a simple click on the GPS will mark its coordinates (latitude and longitude). It will have to be verified beforehand however if it is set in decimal degrees (e.g. 39.4567° with a 4 decimal place position). As it won't be necessary anymore to count the steps, nor to measure the angles in between sequential landmarks, the circumference of the site can be covered a lot quicker. The plotting of the landmarks on paper can be done by introducing manually all the coordinates of the landmarks into a computer or (even more rapidly) by connecting the GPS directly to the computer to download them, using an appropriate software program. Be also aware that the imprecision of a GPS can be as high as 10 m, which might be a problem for small study sites, but not for big ones.
- A car could also be used to do the mapping, certainly for very big sites. The distances could be measured with the odometer of the car, but be aware that the precision is only 100 m. The use of a GPS is certainly recommended in this case.

T.B. 1.03 Area sampling

Area sampling is an assessment method that, starting from the mapping method, provides the possibility to estimate the number of people living in a particular area or to have an idea of the magnitude of the population displacement towards a specific site. This population figure also provides a denominator for epidemiological and program indicators. With the surface of the target area and its estimated population, it's even possible to analyse the average available area per person.

Procedure

- Count on the map that was obtained by the mapping method (T.B. 1.02.) from left to right and from top to bottom all the complete 25 m x 25 m squares. Do not include the partial squares, even if they have more than half of their surface inside the perimeter. *The number of complete squares on the figure equals 50.*
- Select on the map through systematic sampling at least 15 complete squares (of 25 m x 25 m) that need to be visited to collect data (area sampling).
 - Divide the total amount of complete squares by 15, and round off this result to a non-decimal number. The rounded off number is the systematic sampling step (*figure: $50/15 = 3,33$ rounded off to 3*).
 - Start from the first complete square on top of the grid and add towards the right-hand side the systematic sampling step to obtain the second complete square for area sampling. The systematic sampling step can only be counted on complete squares, partial squares within the perimeter should be ignored.
 - Keep on adding the systematic sampling step from left to right and top to bottom until 15 complete squares are selected. When the systematic sampling arrives at the bottom of the grid and there aren't 15 complete squares selected yet, the step is continued at the top of the grid.
- Go to an outer landmark of the site.
- Measure on the map the bearing from the outer landmark towards the lower left corner of the first selected square. This is done by placing the compass with its long edge on the existing map along the line formed from the chosen outer landmark until the lower left corner of the selected square, making sure that the direction arrow is pointing towards the selected square. The rotating graduation ring is then rotated until its arrow is pointing to the north (top) of the map (parallel lines of the rotating graduation ring are exactly in line with the vertical lines of the graph paper). The bearing can be read on the graduated ring at the position of the direction arrow (T.B. 1.02.).
- Measure on the map the scale length in between the outer landmark and the lower left corner of the selected square, adapt it to the real distance according the scale of the map and convert it in number of footsteps (average length of footsteps should be known; T.B. 1.02).
- Go to the selected square on the site by means of the measured bearing and distance (number of footsteps), starting from the chosen outer landmark. By turning the rotating graduation ring until the bearing is in position with the direction arrow and having the graduated ring arrow in position with the magnetic needle indicating north, the direction to go in is determined.
- Form a square of 25 m x 25 m (4 ropes with marking at 25 meters can be of help to determine the square), starting from the left bottom corner as indicated on the map. Shelters on the edge that don't fall completely within the 25 m x 25 m square should only be included in the sample if they have at least their south and east limits within the 25 m x 25 m square.
- Visit dwelling per dwelling within the 25 m x 25 m square and note the number of persons who have spent the previous night at each dwelling to determine the size of the household. Additional information on the age and sex of the household members can also be collected.
- Keep on doing the same procedure for all the selected squares.

A**B**

Calculations

- Calculate the **population of each square** by adding up all household members per square. Note the figures down.
- Calculate the **average size of a household** by adding up all the figures of the population of each square, divided by the total number of households visited. Note the figure down.
- Calculate the **average population per square** by adding up all the figures of the population of each square, divided by 15. Note the figure down.
- Extrapolate the **total population of the site** by multiplying the average population per square with the total number of squares within the perimeter (complete squares and partial ones which have more than half of their surface included).
- Calculate the **average available area** (number of m² per person) by dividing the total surface of the site (T.B. 1.02) by the total population of the site. This figure should be compared with the site planning indicator (T.B. 1.10.).

Key	Input
A. Systematic sampling	
B. Survey technique	
1. Map obtained by the mapping technique	- Map
2. Selected squares of 25 m x 25 m (at least 15)	- Ruler
3. Direction from chosen landmark to selected square (angle and distance; in occurrence square 10)	- Compass or GPS
4. Surveyors	- Long tape measure (e.g. 50 m)
5. Persons delimiting square of 25 m x 25 m	- Hand clicker
6. Ropes	- Notebooks and pens/pencils
7. Hut with south and east limits inside 25 m x 25 m square	- 4 Ropes
8. Hut with east limit outside 25 m x 25 m square (excluded)	- Calculator
	- 2 surveyors
	- 4 persons delimiting square.

Remarks

- The calculated total population of the site is not an exact figure but a good estimation of the reality.
- In order to obtain a representative figure of the total population of the site, at least 15 complete squares are required to be investigated of which at least 10 need to be populated. Only habitats for which at least half of the surface falls within the selected square should be included in the persons count. It is strongly recommended to give each selected square a number in order to avoid confusion afterwards (e.g. visiting the same square twice, mixing up figures of different squares).
- In case there would be a clear distinction in population density within the site, the area sampling will have to be done separately for the high and low density areas. Otherwise the calculated figures (e.g. extrapolation of the total population) could give a completely false result.
- When a big part of the study site is uninhabited (e.g. a lake), it should be mapped separately and deducted from the total study site surface, in order not to falsify the extrapolated population estimation.
- The visit of the selected squares is also a good opportunity to do some informal talks with the population and some spot-check observations (T.B. 1.0.1) inside and outside of the dwelling on issues that are of interest for the program (e.g. water, hygiene and sanitation related).

T.B. 1.04 Health structure checklist

This checklist helps to prepare general data collection during assessments within health structures. The collection of unnecessary data is surprisingly easy to do, but frustrating and inefficient. So always double-check the relevance of all the data to be collected.

Key criteria

Context

- What is the field of intervention: e.g. assistance to victims of conflict or natural disaster, assistance to vulnerable groups in post-emergencies, epidemics or endemics, access to healthcare for excluded groups?
- Is it an acute or chronic emergency, or a stabilized situation? What is the foreseen project duration?
- What is the location of the health structure: camp, rural, urban? Is it located on private or public terrain?
- What kind of health structure: e.g. out-patient (OPD), in-patient (IPD), hospital, therapeutic feeding centre (TFC), cholera treatment centre (CTC) or unit (CTU)?
- How many consultations and/or in-patients/day, number of beds (occupancy rate)?
- What are the activities of the health structure: e.g. surgery, enlarged program of immunization (EPI), maternity?
- What is the (local) management organisation of the health structure? What is the involvement of aid-agencies in the health structure: e.g. owner, technical support, continuous presence, training? What is the role of MOH, others?

Land availability

- Is there space available for a potential extension of the health structure, or to install temporary emergency facilities: e.g. during an outbreak?
- Is there space available to build new facilities: e.g. latrines, waste zone?
- Is there a signature of agreement prior to the utilization of private ground?

Access

- Is the health structure easy accessible for patients? What is the distance / time the patients have to travel to arrive at the health structure?
- Is the health structure always accessible by an ambulance?
- Is access possible at all times of the year for heavy transport vehicles: e.g. medical material and equipment, building material, water supply?

Legislation / land rights

- To whom does the land of the health structure compound belong?
- Can (additional) semi- and/or permanent structures be build on the compound?
- Is there a national legislation concerning water supply, medical waste, insecticides use (try to get a copy if existing)? Is it applied in the health structure?
- Is there a Hygiene Committee?

Existing facilities on the health structures compound

- Is the layout of the existing buildings and facilities appropriate? Does a map exist? (if not, make one; T.B. 1.02).
- Are there sufficient and appropriate latrines, showers, washing facilities, a waste zone, a kitchen?

Human resources

- Is there a responsible for the correct implementation and follow up of the essential water and sanitation requirements in the health structure (T.B. 1.08)? Is health promotion ongoing or planned?
- What is the total number of staff present: e.g. doctors, nurses, lab technicians, cleaners, technicians?
- What is their number, divided in national and expatriate staff?
- Is all the staff aware about correct hygienic behaviour within the health structure (standard / universal precautions)? Did they receive any training / information concerning this topic? Are there hygiene / health promotion activities ongoing or planned for the staff?
- Are needle stick injuries reported? How often does it happen? Is there a protocol for Post Exposure Prophylaxis (PEP) available after the injury?
- Has the national staff been vaccinated against Hepatitis B / tetanus (medical and non-medical staff)?
- Does all the staff have protective clothing (medical and non-medical staff)?
- Are there cleaning products, disinfectants and equipment available, and if so, which kinds? Are the protocols of correct cleaning (e.g. latrines, wards) / disinfection / sterilisation available and practiced?

Security / safety

- Are there security considerations for the staff, the patients, the visitors or the surrounding population: e.g. armed individuals trying to get access to the health structure?
- Are there safety considerations for either the staff, the patients, the visitors or the surrounding population: e.g. presence of open pits, waste exposed on the ground, location of the latrines / showers?
- Is there a big fire risk? Are there evacuation plans?

Climate

- What is the period and duration of the rainy season / cold period (winter)? Does it have an influence on the material and equipment supply? Does it have an impact on the drainage?

Water

- Are water resources available within or around the health structure compound? The further the water resource is away, the more complex and expensive the water supply will become.
- What kinds of resources are available: surface water, groundwater, rainwater catchments? Are the existing water resources available all year around?
- Do the available resources provide all year around sufficient quantities for all activities within the health structure (e.g. sterilisation, general hygiene, drinking, cooking, personal hygiene and sanitation)? What is the quality of the water? Is water easy accessible for staff, patients and visitors?

Terrain

- Is the land sloping gently for natural drainage?
- What is the soil type of the health structure's compound (important for its infiltration capacity, ease and safety of digging)? What is the depth of the highest water table (at the end of the rainy season)?
- Is the health structure located in a flood prone area, nearby a swamp, on land with a high water table or at risk of land slides? Is or will the groundwater be used for the health structure or by the surrounding population?
- What is the dominant wind direction: e.g. for latrines or incinerator construction?

Environmental Health Risks

- Are there any vector borne diseases endemic to the area and if so, is the health structure sited in a high or low risk area?
- Are there any visible signs of vectors (organisms, faeces, eggs; T.B. 7.0.1 to 7.0.9), or nuisances related to them?
- Is there stagnant water, or other potential vector breeding sites on site or in the close vicinity?

Local Communities

- What is the distance in between the health structure's compound and the neighbouring dwellings?
- Are there any socio-cultural problems linked with the health structure (e.g. latrines, dead bodies)? Is the population surrounding the health structure complaining about certain activities within the compound (e.g. incineration of waste that is generating smoke)?
- Do the wastes generated within the health structure have any commercial value for the population? Do you find them back on the local market (e.g. needles and syringes, expired drugs)?
- Is the community aware of the activities within the health structure?

Remarks

- Although this checklist encloses the most essential health structure information, it is not exhaustive.
- This checklist should be used in combination with the water, hygiene and sanitation checklist (T.B. 1.06).
- Some of the collected data (based on this checklist) can be compared during the analysis with the indicators listed in the essential water and sanitation requirements for health structures (T.B. 1.08).

T.B. 1.05 Camp checklist

This checklist helps to prepare general data collection during assessments within refugees / displaced persons camps. The collection of unnecessary data is surprisingly easy to do, but frustrating and inefficient. So always double-check the relevance of all data to be collected.

Key criteria

Context

- What is the field of intervention: e.g. assistance to vulnerable groups in post-emergencies, epidemics or endemics, access to healthcare for excluded groups, assistance to victims of conflict or natural disaster?
- Is it an acute or chronic emergency, or a stabilized situation?
- What is the location of the camp: rural, urban? Is it located on private or public terrain?
- What is the population size of the camp: e.g. total number of people, age / gender repartition?
- Is there an integration or not within the resident population? What is the distance to residents dwellings?
- What is the involvement of aid agencies in the camp: e.g. medical infrastructure (in-patient / out-patient departments), nutrition, technical support, water, hygiene and sanitation, training?

Land availability

- Is there sufficient land area available (also for possible future extensions; T.B. 1.03)?
- Is there the possibility of self-sufficiency for the population (e.g. the right to use the land for agricultural purposes)? Is it easy to supply food and materials to the camp?

Access

- Is access possible at all times of the year, particularly for heavy vehicles (e.g. water trucks)?
- Are communal facilities always accessible by light vehicles?

Legislation / land rights

- Are there any legal and/or traditional rights that have to be considered?
- Can semi- and/or permanent structures be build on the site?
- Will it be possible to install a landfill / cemetery and will there be enough space?

Existing facilities on the camp site

- Are there health structures implanted on the site, or buildings that could be used as such?
- Are there (large) buildings that could be used as an office / a warehouse?
- Is there a market? What are the main goods that can be found (food and non-food items)?
- Are there religious buildings (mosque, church, temple), even under temporary shelter?

Security / safety

- Are there security considerations for either refugees, displaced persons or relief workers? It is recommended that refugees will be settled at a reasonable distance from international borders and other potentially sensitive areas.
- Are there safety considerations for either refugees, displaced persons or relief workers: e.g. presence of open pits, waste exposed on the ground, location of the latrines / showers?
- How high is the risk of fire? Are there firebreaks? Are there evacuation plans?

Climate

- What is the period and duration of the rainy season / cold period (winter)? Does it have an influence on the material and equipment supply? Does it have an impact on the drainage?

Water

- Are there water resources available onsite or nearby, all year around? The further the water resource is away, the more complex and expensive the water supply will become.
- What kinds of resources are available; surface water, groundwater (including spring water), rainwater catchments? Are the existing water resources available all year around?
- Is there sufficient water quantity provided for drinking, cooking, personal hygiene and sanitation for the projected population? How is the water quality? Is water easily accessible, also for vulnerable people?

Terrain

- Is the land sloping gently for natural drainage?
- Is the soil type suitable for digging and water infiltration? The soil type determines which sanitation and construction techniques may be used. Avoid rocks or areas with a high water table, as it will make latrine construction difficult.
- Are there sufficient grass shrubs and trees for shade and to prevent soil erosion?
- Is the camp located in a flood prone area, nearby a swamp, on land with a high water table (what is the depth of the highest water table) or at risk of landslides?
- What is the dominant wind direction: e.g. for latrine localization?

Environmental Health Risks

- Are there any vector born diseases endemic to the camp area? Is the camp located in an area with risks such as malaria, bilharzias (schistosomiasis), sleeping sickness (trypanosomiasis)? Is it a high or a low risk area?
- Are there visible signs of vectors (organism, faeces, eggs; T.B. 7.01 to 7.09), or nuisances related to them?
- Is there stagnant water, or other potential (and avoidable) vector breeding sites on site or in the close vicinity?

Local Communities

- Does the camp create a negative (environmental) impact on its surroundings: e.g. deforestation, soil erosion, poaching, sharing of scarce water resources? The possible impact this may have on local communities is important and has to be taken into consideration.
- Is there tension / collaboration between the local community and the refugees / displaced persons?

Human resources

- Is it possible to recruit people within the camp population or from the local communities?
- Are there skilled people (e.g. nurse, water and sanitation technician, hygiene promoter) amongst the camp population or the local communities?
- Are there other aid-agencies present (national and international)? What is their field of activities? Is there a collaboration / coordination in between the different agencies?
- Are there hygiene / health promotion activities ongoing or planned?

Remarks

- Although this checklist encloses the most essential camp information, it is not exhaustive.
- This checklist should preferably be used in combination with the water, hygiene and sanitation checklist (T.B. 1.06).
- Some of the collected data (based on this checklist) can be compared during the analysis with the indicators listed in the essential water and sanitation requirements and the site planning for camps (T.B. 1.09 and 1.10).
- The selection and planning of a new site is usually done by official instances (e.g. UNHCR, local authorities), but involvement of NGOs is recommended.
- The selection (and planning) of a site should preferably be done by a multidisciplinary team that consists of a medical person, a logistician and a water, hygiene and sanitation technician / engineer.
- In the initial phases of the emergency it is very hard to gauge, with any confidence, the likely duration of the camp. Therefore it is best to select, plan and install the site within the briefest delay possible. However, as the camp may remain for many years, a long-term view is recommended from the beginning.
- Unused or unoccupied sites often have a good reason for not being used, and the ideal site often remains a dream.

T.B. 1.06 Water, Hygiene and Sanitation checklist

This checklist helps to prepare specific data collection related to water, hygiene and sanitation during assessments within health structures or refugee / displaced persons camps and communal centres. The collection of unnecessary data is surprisingly easy to do, but frustrating and inefficient. So always double-check the relevance of all data to be collected. The focus should be mainly on the water, hygiene and sanitation issues that have a health impact.

Human resources

- Who is in charge of the local water, hygiene and sanitation systems, and who is responsible for their maintenance and repairs?
- Is there local expertise for repair or rehabilitation of the different systems?
- Which organisations are already involved, are realistically available and have the capacity to work in water, hygiene and sanitation programs (e.g. NGO's / Red Cross / UN / Ministry of Works)?
- Is there a need for a water and sanitation specialist?

Hygiene

General information

- Are there hygiene-related diseases present including faecal-oral diseases, trachoma, scabies? Cross check morbidity statistics with the medical staff.
- Is there a presence of vectors that are related to lack of (personal) hygiene (e.g. fleas, lice)?
- Is there sharing of beds, bed linen, towels, clothes amongst people / patients?
- Are containers, which may be mosquito breeding sites, removed, emptied regularly or covered?

Facilities

- Is soap available and used for hand washing, body washing and laundry? Are there alternatives available / used to replace soap, like ashes?
- Is there a sufficient quantity of water for personal hygiene and health structure / domestic cleaning?
- Are hand-washing facilities available in sufficient quantity? Are they accepted by the beneficiaries? If not, why? Are there some hand washing facilities located inside the health structure services / wards and / or near the defecation facilities?
- Are showers available in sufficient quantity? Are they accepted by the beneficiaries? If not, why? Are they located in a safe and accessible place?
- Are laundry facilities available in sufficient quantity? Are they accepted by the beneficiaries? If not, why? Are they located in a safe and accessible place?
- For all those facilities, is there a presence of an appropriate drainage system: e.g. grease trap, soak away pit, infiltration trenches?
- What goods are women normally using during menstruation? What supplies are available? Are there special facilities foreseen where the (fabric used as) sanitary towels can be collected / washed?

Operation and maintenance

- What is the general level of hygiene practised by the health structure staff, patients and accompanies / targeted population? If it is poor, why? Is it due to lack of soap or water, or other reasons?
- What is the frequency and type of general cleaning (in health structures, communal centres): e.g. cleaning of floors and surfaces with detergents, airing and cleaning of mattresses? Who is responsible?
- Are all the specific hygiene facilities used (correctly)? If not, why?
- Are the specific hygiene facilities clean / maintained inside, but also outside?
- How is the cleaning organized? Who is responsible? What procedures are used? Is cleaning material available (e.g. brooms, soap, chlorine)? What is the maintenance frequency?
- What is the frequency and type of laundering clothes and bedding? Who is responsible?
- How is the food hygiene: preparation, storage and cleaning of utensils / crockery? Who is responsible?
- Are hygiene / health promotion activities ongoing or planned? By who is it done and who is targeted?

Water

General information

- Verify the quantity, quality and accessibility of the various water related facilities because the combination of these factors determine their final usage, and therefore have an influence on the related health risks.
- What is the amount of available water, in litre per patient / person a day? Is this amount available every day or is the supply irregular?
- Are there water-related diseases present, including faecal-oral diseases, guinea worm, bilharzias? Cross check with the morbidity statistics of the medical staff.
- Is the water free of charge? If not, is it affordable for all?
- Is there a seasonal impact on the quantity, quality and accessibility of water?

Facilities

Quantity

Determine the available water resource(s), the available water quantity and reliability of each resource:

River/stream

- What are the estimated width and depth? Is the water moving fast or slow? These are all indicators of the capacity of the resource; even a small and shallow river with a good flow has already a decent water capacity.
- Does water flow during the whole year?

Lake

- Is it a big or a small lake? Be aware that when large amounts of water are taken for a prolonged time, a small lake can dry up.
- Are there any rivers discharging in the lake? Are they rivers with a high water capacity?
- Does the lake reduce in volume or even dry up at certain periods of the year?

Hand dug wells / boreholes

- What is the quantity of water that the hand dug well / borehole can deliver per hour or per day?
- Does it give water all day or does it dry up during certain hours; if it dries up, for how long?
- How many hours a day do people use water from this resource?
- What is the static ground water level in the area (during dry and rainy season)?

Spring

- What is the estimated discharge of the spring? Measure the time needed to fill up a bucket of known volume.
- Is the discharge of the spring stable during the whole year? Does the spring dry up during the year?

Rainwater

- What is the rainfall pattern over the year? These figures might be available in meteorological stations, universities or on the internet.
- What are the periods of dry and rainy seasons?

Quality

Check for possible contamination of the water resources:

- Is there a risk of micro-biological or chemical contamination: e.g. open defecation, latrines, laundry, intensive agriculture (e.g. animals, pesticides, fertilisers), industry (e.g. mining)? What is the distance of the resource to latrines, waste disposal sites, farms, workshops, industry?
- How is the resource protected: e.g. intake system protection, zone fenced off, drainage ditch, overflow, drainage channels?

Check the water quality:

- How is the colour, smell, taste, turbidity (turbidity tube; T.B. 2.13), pH (pool tester; T.B. 2.22)?
- Does the water contain a lot of minerals / salts? If the adapted equipment is available, check the conductivity of the water.

Check if water treatment is being done:

- Is chlorine locally available? Is the water chlorinated? Measure the Free Residual Chlorine (FRC) concentration (with a pool tester; T.B. 2.22) at different locations (e.g. water reservoirs, piped systems).
- Is assisted sedimentation performed? Is it a batch or continuous system?
- Are there filtration systems installed and used? What type of filters is available? What is the frequency of the backwashing?

Accessibility

Check the water supply system:

Resources

- Are the resources nearby or far away from the user point?
- Are the resources foreseen with the necessary equipment to facilitate the accessibility (e.g. hand pump on a well, submersible pump on a high-yield borehole, motor pump at a river)?

Water trucking

- Is there enough capacity to fulfil the water needs (e.g. number and condition of the available trucks, condition of the roads, rotation time per fill up)?
- How is the water trucking organized (e.g. private or authorities trucks, conditions of the contract related to duration, human resources, running and maintenance costs)?

Piped water supply

- How many hours per day is the water system providing water?
- Is it a gravity or pumped system?

Water reservoirs

- How many reservoirs are installed?
- What is the capacity of the reservoirs? How many hours per day are the reservoirs full of water? How often are they refilled?
- Where are the reservoirs located (e.g. nearby the health structure, spread within the camp)? Are they easily accessible for water trucks?

Check the location of water distribution points:

- Are the water distribution points easily accessible to the beneficiaries, if not why?
- Are taps (stands) available?

Check if everyone has the means to transport and to store water at their dwelling:

- What is the number of water containers per household, their capacities and the average number of refills (to estimate the total amount of water collected per day)?
- What type of containers (e.g. plastic jerry cans, clay pots, tins) are the beneficiaries using? Are these the kind of containers they would normally use?
- What is the condition of the containers (e.g. clean, damaged)?

Operation and maintenance

- Is there safe and perennial access to water for all groups; especially the most vulnerable? Are certain groups denied access? If so, why?
- How long do the users have to wait for water? Is queuing observed (e.g. empty jerry cans left behind), is there crowding / fighting at water points?
- How often is the water quality checked? What kind of checks are performed?
- How often are the water quality treatment systems checked and maintained? What is the protocol / procedure of the assisted sedimentation, filtration and chlorination processes (if applied) and their frequency?
- Is cleaning of the beneficiaries' containers done (systematically)? What is the procedure?

Excreta disposal

General information

Verify the quantity, quality (including the maintenance) and accessibility of the various excreta disposal facilities because the combination of these factors determine their final usage, and thus have an influence on the related health risks.

- Is there a lot of excreta laying around? Is wild defecation a normal practice? Are people defecating in surface water (e.g. river, lake)?
- Are there excreta-related diseases present, including faecal-oral diseases, bilharzias? Cross check with the morbidity statistics of the medical staff.

Facilities

- What types of excreta disposal facilities are to be found: defecation areas / trench latrines / improved trench latrines / simple pit latrines / VIP latrines / twin pit latrines / pour-flush latrines / flush toilets / septic tanks / sewage system / others?

Quantity

- What are the number and layout of the defecation facilities in the concerned area?
- What is the average number of persons per defecation facility? Are the defecation facilities provided per family (or group of families) or are they communal facilities?
- What is the capacity of the defecation facilities? Are there extension plans if the number of people increases?

Quality

- Are the defecation facilities adapted to the users' preferences and limitations: e.g. physically impaired people, staff – patient / gender – family separation, are people washers or wipers, squatters or sitters?
- Is there a proximity of excreta disposal facilities to water resources and water distribution points? What is the highest static ground water level in the area?
- Is the latrine construction safe (e.g. pit not too deep, lined pit, lining and slab material that can't rot or being infested with termites)?
- Do the defecation facilities prevent vectors from breeding / feeding in excreta (e.g. is the lid put back on the defecation hole of a simple latrine, is the net on the ventilation pipe of the VIP latrines intact)?
- Does the latrine superstructure provide any potential breeding sites for vectors?
- Is local material used / available for the construction of excreta disposal facilities? Can the use of local materials have a negative impact on the environment (e.g. deforestation)?

Accessibility

Check the location of the defecation facilities in the concerned area:

- What is the minimum and maximum distance in between the defecation facilities and shelters / buildings? Are there defecation facilities foreseen at public areas (e.g. market, food distribution points, health facilities)?
- Is there safe and perennial access to the facilities for women, children, disabled or handicapped people, as well as for vulnerable groups? Are the defecation facilities situated in a safe location to avoid sexual violence? Is lighting provided for use at night?
- Are (hand) washing facilities (with water and soap) and waste bins available in the direct proximity?

Operation and maintenance

- Are the defecation facilities used (correctly)? If not, why?
- What are the materials used for anal cleansing?
- Are the defecation facilities clean / maintained inside but also outside? Is there any visible open defecation (look behind old buildings and outskirts)?
- How is the cleaning organized? Who is responsible? What procedures are used? Is cleaning material available (e.g. brooms, soap, chlorine)? What is the maintenance frequency?
- Is there a significant presence of flies? Are there any visible signs of (other) vectors (organisms, faeces, eggs; T.B. 7.01 to 7.09) in the latrines?

Runoff and wastewater

General information

- Are there any areas of stagnant water: e.g. puddles, blocked gutters, open (domestic) water containers indoors and outdoors, plant pots, open water storage tanks?
- Are there vectors present, breeding in / living around stagnant water (e.g. mosquitoes)?
- Are there specific diseases present related to vector breeding in / living around stagnant water including malaria, dengue, yellow fever? Crosscheck with morbidity statistics.

Facilities

- Are there any open drainage channels and if so, are they maintained regularly to avoid blockages and formation of standing water?
- Is there a separated evacuation system for runoff and wastewater?
- How is runoff water controlled? Presence of drainage ditches, sewer system (open or closed), others?
- Where is the runoff water led to (e.g. river, stream, lake, sea, water treatment plant)?
- How is the wastewater controlled? Is there a presence of drainage ditches or pipes, a sewer system (open or closed), others? Are there soak away pits / infiltration trenches / evapo-transpiration areas / gardens (only for spilled clean water) available? Are they all provided with grease traps?

Operation and Maintenance

- Do the people / staff use the right facilities to dispose of wastewater (e.g. sinks)?
- Are the runoff and wastewater evacuation facilities correctly maintained? Is the grease layer of the grease trap removed and at what frequency? Where is this grease layer disposed of? Who is responsible for the maintenance of all the runoff / wastewater facilities? What are the procedures used? Is maintenance material available?

Refuse (domestic solid waste) disposal

General information

- What types of solid waste are generated and in what quantity?

Facilities

- Are waste collection containers available and what types if present? Do they have holes to evacuate the leachates? Do they prevent vectors from breeding / feeding in the waste (e.g. garbage bins with lids)? What is the quantity and location of the waste collection containers?
- What kind of waste collection and treatment / disposal system is available: a household or collective system? What means are available for the collective waste collection? How is the waste treated / disposed of (e.g. household refuse pits, open fire, incinerator, dumpsite, controlled landfill)? Do these facilities prevent vectors from breeding / feeding in the waste (e.g. waste pits covered daily with an compacted layer of soil)?
- Is there a risk of contamination of water sources due to proximity?

Operation and maintenance

- Do the people put their waste in the household refuse pits or collective waste bins? If not, why? In case of household refuse pits, do the people cover it with a lid / compacted soil each time new garbage is introduced?
- What is the frequency for the collective waste collection and the treatment / final disposal? Who is responsible?
- Is maintenance material for the collective waste bins, the transport means and treatment / final disposal facilities available, and what kind? Is the maintenance done of these facilities and their surroundings?

Medical waste

General information

- Is the medical waste segregated in different categories? What are the different categories? How much waste of each category is generated per day (kg/day)? What is done with hazardous waste (e.g. lab waste, pharmaceutical waste)?
- Are there any socio-cultural problems linked with medical waste?
- Do the wastes generated within the health structure have any commercial value for the population? Do you find them back on the local market (e.g. needles and syringes, expired drugs)?
- Is there a national legislation concerning medical waste (try to get a copy if existing)? Is it applied in the health structure?

Facilities

Check the recipients used to collect the waste per category:

- What materials are locally available for collection of waste: e.g. plastic 20 l buckets with tight fitting lid of different colours? Are there specific containers for sharps? Are those safe?
- Are there separate recipients to collect the waste of the patients, visitors and attendants?

Check if the treatment and/or final disposal of medical waste is done within or outside the health structure compound:

Within the compound

- How is the treatment and / or final disposal done for the different kinds of waste? Is there a presence of a volume reducer or incinerator, safety box reducer and/or glass crusher? Are there sharps, soft and/or organics waste pits available? If not, are materials locally available for the construction of the different facilities: e.g. concrete rings for a sharps pit, refractory cement and bricks for an incinerator?
- Is a waste zone, grouping all the facilities, present on the compound? Where is it situated within the compound (distance to buildings, dwellings, dominating wind, good access)? Is the waste zone protected to avoid non-authorized persons to enter?

Outside the compound

- Where is the waste treated / disposed of? Is it done under safe and controlled conditions? Are there appropriate vehicles to do the waste transport towards the treatment / disposal area? Who is responsible for the transport and treatment / final disposal of the medical waste? Are waybills made?

Operation and maintenance

- Is the medical waste being segregated by the medical staff in the treatment rooms / wards according to the correct categories?
- Are there disinfecting and cleaning facilities available for the waste recipients?
- How often are the (different categories of) wastes being removed from the treatment rooms / wards? Who is responsible? Is the person adequately trained and equipped for this job?
- What is the treatment and/or final disposal frequency? Is it done in an acceptable way? Is there a waste manager? If not, who is responsible? Is the person adequately trained and equipped for this job?
- How is the waste zone maintained (e.g. procedure, frequency, maintenance of the material)?

Vector control

General information

Assess the risk of vector-borne diseases and verify the clinical evidence of the disease among the affected population. Advice should be sought from local authorities on local disease problems and the available vector-control resources. The assessment should focus on the following:

- Is there a difference between epidemic and non-epidemic disease or risk?
- Is the transmission all year round, or is it seasonal transmission at particular times?
- What is the immune status of the population? What is the distribution of vulnerable groups (e.g. children under five, pregnant women, movements of population from low to high transmission zones or vice versa)?
- What is the pathogen type and its prevalence?
- What is the vector species' behaviour (e.g. mosquito species that feed and rest indoors at night), and habitat (e.g. stagnant water, open defecation areas, wet latrines, garbage)?
- What is the vector density (e.g. seasonal influence, number of potential breeding sites)?
- Are there existing individual protection and avoidance measures (e.g. are the general water and sanitation facilities in place and maintained)?
- What are the knowledge, attitude and practice factors in the affected population (e.g. how do people think the disease is transmitted, who is considered vulnerable, what do people know about prevention activities, what are the perceptions about pesticides and Insecticide Residual Spraying, are mosquito nets being used, how many mosquito nets are required per household considering the normal sleeping pattern)?

Facilities

Has the affected population the means to protect themselves from vectors that are considered to be a significant risk to health:

- Is control of the human body lice being carried out to an agreed standard where louse-borne typhus or relapsing fever are a threat?
- What is the number of households with Long Lasting Insecticidal Nets? Are they using them (correctly)?
- What is the number of households that is timely sprayed with appropriate, effective and safe insecticide?
- What is the number of households placing bedding in the sun daily?
- Are rodenticides / rodent traps being used?
- Are potential rodent / cockroach entrances (e.g. gaps in floors or doorframes) being sealed?
- Are there fly / mosquito screens on doors and windows?
- Are local approaches of vector control being used?

Operation and maintenance

- Are the vector control activities feasible (e.g. access, security, population mobility, logistics)?
- Is the affected population established in areas with minimal breeding sites of the vector?
- Is the personnel protected by providing training, protective clothing, supervision, and a restriction on the number of hours handling pesticides?
- Are the purchase, transport, storage, disposal of pesticides and application equipment following international norms? Can they be accounted for at all times?
- Are the people informed about the potential risks of pesticides and about the schedule for application? Are they appropriately protected during and after the application of pesticides?
- Are the choice of pesticide and application method conform to national and international protocols (e.g. timing of application / re-application is respected)?
- Is the quality of pesticide and Long Lasting Insecticidal Net conform to international norms?

Dead bodies

General information

- What are the cultural practices regarding funeral procedures (e.g. specific funeral rites, type of cremation, burial)?
- Is there a health risk due to highly contagious diseases (e.g. cholera, Marburg, Ebola, plague)?

Facilities

- Is there a morgue with the needed facilities (e.g. water supply, working tables, safe storage for the deceased belongings, electricity, refrigerator)?
- Is there a cemetery / cremation area?
- What is the distance in between the cemetery / cremation area and dwellings / public buildings / water resources, others? Is there a risk of water resource contamination?

Operation and maintenance

- Who prepares the funeral procedures and who is performing them: relatives, local population, military, aid-agencies?

Remarks

- Although this checklist encloses the most essential water, hygiene and sanitation information, it is not exhaustive.
- This checklist should preferably be used in combination with the health structure and/or camp checklists (T.B. 1.04; 1.05), according to the context.
- The data that have been collected (based on this checklist) can be compared during the analysis with the indicators listed in the essential requirements for health structures / camps (T.B. 1.08; 1.09.)
- This checklist can also be of help during strategy planning (e.g. site planning for camps; T.B. 1.10).

T.B. 1.07 Basic Survey Form

This basic survey form is a ready to use tool which can be applied within the data collection methods during an initial assessment. It will only provide very limited information, but the different checklists presented here above can be of help to adapt this basic survey form to the specific context.

General

Surveyor: Date:
Country: Location:
Area surveyed (e.g. type of health structure, camp):
Population size / patients: Main ethnic group:
Main actors / programs at location:
Climate (e.g. precipitation details, temperature extremes):
Geography (e.g. altitude, type of terrain):
Remarks:

Water supply

Resources:
Condition of the water resources:
Yield/resource:
Number of actual users/resource:
Users other than direct beneficiaries:
Water quality: Turbidity (NTU):
pH:
Free Residual Chlorine (mg/l):
Thermo-tolerant coliforms / E. coli per 100 ml:
Type of water treatment:
Centralized water storage (e.g. bladders) :
Distance of source / distribution points from users:
Condition of water distribution points:
Method of water collection:
Method of household water storage:
Remarks (e.g. implementing organization / opinions and attitudes of beneficiaries / cultural considerations):

Excreta disposal

General impression (e.g. open defecation / presence of livestock):

.....
.....

Type of latrines:

Type of slabs:

Lining of pits:

Remaining depth of pits:

Number of latrines in use:

Number of actual users/latrine:

Condition and usage of latrines:

Location of latrines:

Hand washing facilities:

Availability of soap / ashes:

Remarks (e.g. implementing organization / opinions and attitudes of beneficiaries / cultural considerations):

Drainage / wastewater management

Number of showers:

Number of actual users/shower:

Condition and usage of showers:

Location of showers:

Number of washing / laundry places:

Number of actual users/washing or laundry place:

Condition and usage of washing / laundry places:

Location of washing / laundry places:

Slope of area (%): Drainage pattern:

Stagnant water sites:

Presence and quality of grease traps:

Presence and quality of infiltration systems (e.g. soak away pit at water points, at showers):
.....

Remarks (e.g. implementing organization / opinions and attitudes of beneficiaries / cultural considerations):

Domestic waste disposal

Solid waste disposal system (household or collective) and general cleanliness:

.....

Number, quality and condition of public / household waste bins:

Number and condition of refuse pits / landfill:

Remarks (describe their situation / usage):.....

.....

Medical waste disposal

Segregation of medical waste (categories):

Disposal system (onsite or offsite) and general cleanliness:.....

.....

Type, number, condition and usage of waste bins and sharps containers:.....

.....

Number, condition and usage of sharps pits:

Number, condition and usage of organic waste pits:.....

Type, number, condition and usage of incinerator / volume reducer:.....

Number, condition and usage of ash pits:

Remarks (e.g. implementing organization / opinions and attitudes of beneficiaries / cultural considerations):.....

.....

Vectors

Identify species (if possible) and map sites where most of them are found.

(☺: absent; ☹: present; ☹☹: problematic)

Mosquitoes: ☺/☹/☹☹ Remarks:.....

Flies: ☺/☹/☹ Remarks:.....

Sand flies: ☺/☹/☹ Remarks:.....

Fleas: ☺/☹/☹ Remarks:.....

Lice: ☺/☹/☹ Remarks:.....

Rodents: ☺/☹/☹ Remarks:.....

Mites (Scabies): ☺/☹/☹ Remarks:.....

Other vectors: ☺/☹/☹ Remarks:.....

Current control measures:.....

Remarks (e.g. implementing organization / opinions and attitudes of affected population):

.....

Hygiene

Availability and affordability of soap:

Describe the presence / absence, quality and functionality of:

Individual hygiene practices (e.g. hand washing, use of laundry):

.....

Hygiene / health promotion activities:

.....

Staff:

.....

Training:

.....

Hygiene committees in health structures:

.....

Procedures, equipment, protective clothing for staff (hygiene, cleaning, disinfecting):

.....

Remarks:

.....

.....

Miscellaneous

Describe the presence / absence, general hygiene, sanitary facilities for:

Graveyards:

.....

Schools:

.....

Markets:

.....

Remarks:

.....

.....

T.B. 1.08 Essential water and sanitation requirements for health structures

Adequate water and sanitation provisions are medical requirements, since they are essential for many curative interventions; e.g. water for surgical procedures, delivery room, re-hydration. Water and sanitation provisions are also essential for preventative interventions. The essential water and sanitation requirements allow curative actions to be undertaken, and contribute towards reducing nosocomial infections. The essential requirements are applicable to:

- The smallest health post through to the largest health structure.
- Acute emergencies through to chronic emergencies and stabilised situations.

They are linked to the Standard Precautions and respect the fundamental rule not to harm patients, staff, visitors, and populations surrounding the health structures. In order to have a properly functional health structure, the essential water and sanitation requirements should be reached, or preferably even exceeded. However, the essential requirements are not stand-alone standards. They need to be adapted to the context and should be seen as reference points, not as absolute rules. They are means to come to a functional health structure from a water and sanitation point of view.

Human-related activities required for assessment, planning, training, and promotion

The essential requirements list mainly technical criteria, but it is clear that no intervention can be considered successful if facilities are inappropriate for local conditions, if they are incorrectly used, or if they are not maintained (correctly). The human-related activities must go hand in hand with any technical intervention.

Acute emergency	Chronic emergencies and stabilised situations
<ul style="list-style-type: none">■ Initial assessment and analysis■ Technical training to the staff■ Information to the patients	<ul style="list-style-type: none">■ Initial assessment and analysis■ Set up or strengthen the Hygiene Committee■ In-depth assessment and analysis with the staff■ General and technical training to the staff■ (Health) promotion towards the patients / visitors

Staff management

Ensure that the staff are trained, equipped, and managed correctly:

- Identify and train the Water, Hygiene and Sanitation (WHS) responsible(s)

Small health structures:

→ Cleaner / water and sanitation manager.

Large health structures:

→ Technician / water and sanitation manager.

- Provide the necessary administrative and technical tools:

→ Job descriptions for all staff.

→ Appropriate protective clothing when they are involved in hazardous WHS activities.

→ Appropriate tools.

- Vaccination of the staff who are exposed to health risks: Hepatitis B and Tetanus.

- Provide access to the Post-Exposure Prophylaxis (PEP) kit for the staff exposed to HIV/AIDS risks.

Water

Water quality

Provide water of acceptable quality

“No” pathogens	Free residual chlorine concentration at distribution points ■ 0.2 - 0.5 mg/l (if pH < 8) minimum 30 minutes contact time ■ 0.4 - 1.0 mg/l (if pH > 8) minimum 60 minutes contact time or max 10 E.Coli/100 ml at discharge points if chlorination is really not possible (=> water filters highly recommended)
Low turbidity	■ < 5 NTU ■ < 20 NTU is permissible in an acute emergency
Low concentration of compounds that are acutely toxic or that have serious long-term effects	Context specific; in case of doubt, contact your technical referent
Acceptable to the users	■ Water is not rejected due to colour, taste, odour or salinity

Water quantity and accessibility

Provide adequate quantities of accessible and reliable water

Health structure / activity	Quantity/patient day	Max distance to water source	Min. storage capacity in closable reservoir	
Mobile clinic: infrequent visits	2 l	100 m	1 day	
Mobile clinic: frequent visits (in fixed tents / existing buildings)	5 l		2 days	
Out-Patient Department (OPD)	5 l			
In-Patient Department (IPD) / hospital	40 – 60 l*			
Operating theatre / delivery room (sterilisation not included)	100 l/intervention			
Blanket feeding	0.5 l (5 l if long waiting time)			
Supplementary Feeding Centre (SFC)	5 l			
Ambulatory Therapeutic Feeding Centre (ATFC)	5 l			
In-patient Therapeutic Feeding Centre (ITFC)	30 – 50 l*			
Cholera Treatment Centre (CTC)	60 l			
SARS isolation	100 l			3 days
Viral Hemorrhagic Fever (VHF) Isolation	300 – 400 l*			

* Context dependent: e.g. climate, number of patients (for small number of patients, high quantity range)

- For chronic emergencies and stabilised situations, all quantities should preferably be higher. Keep also in mind that up to 20% of the water can get lost through leaks and spillage.
- Water should be accessible to the staff, patients and visitors.
- Reliable water points should be available within the health structure, certainly at the critical points:
 - **OPD**: consultation room, dressing room, waste zone, nearby latrines, sterilization, Ante Natal Care and immunization, pharmacy.
 - **IPD / hospital**: operating theatre, maternity, sterilization, laboratory, waste zone, nearby latrines / toilets, kitchen, morgue, all wards, laundry, pharmacy, emergency.
- All water collection points must be maintained at least once a week.

Excreta disposal

Provide adequate and appropriate excreta disposal facilities

In sufficient quantity	In-Patient health structures (e.g. IPD, ITFC) <ul style="list-style-type: none"> ■ 1 latrine/20 users → assume each patient has 1 visitor / attendant → (1 + 1 for staff) + (N° of beds x 2)/20 OPD <ul style="list-style-type: none"> ■ 1 for staff + 1 male + 1 female + 1 children's latrine (or potties)
Technically appropriate (depending on local constraints)	Acute emergency <ul style="list-style-type: none"> ■ Improved trench latrine Chronic emergencies and stabilised situations <ul style="list-style-type: none"> ■ Pit latrine / children latrine ■ VIP latrine / Double pit VIP latrine ■ (Pour) flush latrine (potentially with septic tank and infiltration system or closed sewer)
Appropriate for the users	<ul style="list-style-type: none"> ■ Facilities must be culturally and socially appropriate ■ Separate facilities for staff and patients ■ Preferably a separation between male and female (certainly if culturally necessary) ■ In-patient health structures (e.g. IPD, ITFC): some latrines provided with seats and handlebars for physically impaired persons ■ Children's latrines provided near to paediatric ward and feeding centres (or potties) ■ Bed pans / urine flasks (or similar local material) for bedridden patients
Easily accessible	<ul style="list-style-type: none"> ■ Distance of improved trench / pit latrines: > 5 m and < 30 m from buildings
At safe location	<ul style="list-style-type: none"> ■ To avoid risk of sexual violence ■ Night lights provided and operating (if feasible)
Convenient hand washing facilities	<ul style="list-style-type: none"> ■ Soap, hand washing and wastewater facilities provided at exit of latrines
Prevent contamination of water resources	<ul style="list-style-type: none"> ■ Latrines > 30 m away from water resources

All excreta disposal facilities must be maintained at least once a day.

Wastewater disposal

Provide bathing facilities

In sufficient quantity	In-Patient health structures (e.g. IPD, ITFC) <ul style="list-style-type: none"> ■ 1 (bucket) shower/40 users → assume each patient has 1 visitor / attendant → (1 + 1 for the staff) + (N° of beds x 2)/40 OPD <ul style="list-style-type: none"> ■ (bucket) shower (in case of scabies or sexual violence)
Appropriate for the users	<ul style="list-style-type: none"> ■ The facilities must be culturally and socially appropriate ■ Separate facilities for the staff and patients ■ Separation between male and female (small children can go to the women's showers) ■ In-Patient structures: some showers provided with seats and handlebars for physically impaired persons
At safe location	<ul style="list-style-type: none"> ■ To avoid risk of sexual violence ■ Night lights provided and operating (if feasible)
Related facilities	<ul style="list-style-type: none"> ■ Water supply close by (maximum 5 to 20 m walking distance) ■ Showers connected to wastewater facilities

All shower facilities must be maintained at least once a day.

Provide washing areas for In-Patients structures

Separate washing areas for	<ul style="list-style-type: none"> ■ The dishes, if a kitchen is present ■ The structure's laundry (e.g. bed sheets) with sufficient drying lines ■ The patients' laundry (if required)
Appropriate for the users	<ul style="list-style-type: none"> ■ The facilities must be culturally and socially appropriate
Related facilities	<ul style="list-style-type: none"> ■ Water supply close by (maximum 5 to 20 m walking distance) ■ Washing areas connected to wastewater facilities

All washing areas must be maintained at least once a day.

Provide adequate wastewater disposal facilities

Type of wastewater	Pre-treatment	Disposal	Distance between disposal and water resource
"Clean" wastewater e.g. from tap stand, hand pump (without soap, oil, grease)	No	<ul style="list-style-type: none"> ■ Soak away pits (emergency) ■ Infiltration trenches ■ Evapo-transpiration area (arid zones) 	> 30 m
		<ul style="list-style-type: none"> ■ Properly sealed sewer system. 	
"Dirty" wastewater (grey water with soap, oil, grease)	Grease trap	<ul style="list-style-type: none"> ■ Soak away pits (emergency) ■ Infiltration trenches ■ Evapo-transpiration area (arid zones) 	> 30 m
		<ul style="list-style-type: none"> ■ Properly sealed sewer system 	
Black water (overflow of a septic tank)	Septic tank	<ul style="list-style-type: none"> ■ Soak away pits (emergency) ■ Infiltration trenches ■ Evapo-transpiration area (arid zones) 	> 30 m
		<ul style="list-style-type: none"> ■ Properly sealed sewer system 	
Rain and runoff water	No	<ul style="list-style-type: none"> ■ Natural drainage 	

All waste water collection systems and grease traps must be maintained at least once a week.

Medical waste disposal

Provide a safe and secure segregation, collection and temporary storage, potential treatment and final disposal of all types of waste.

General

- Install the waste containers for patients / visitors at maximum 5 to 20 m walking distance from where the waste is generated.
- Provide 3 (single use) sharps, 3 soft and 3 organic waste containers per ward (with maximum 20 beds) / treatment room, one for use, one for rotation (kept in the waste zone after cleaning and disinfection), one for spare (kept in the ward).

Operating theatre

Nearby the operating table, install:

- 2 sharps containers, 1 for the surgeon, 1 for the anaesthetist.
- 2 soft waste containers of 20 l, 1 for the surgeon, 1 for the anaesthetist.
- 1 big soft waste container of 60 l (in case the sterilised material is kept in Kraft paper, which will help to light the volume reducer / incinerator, if kept dry).
- 1 big organic waste container.

All waste containers should be available in threefold as described above (general).

Ambulance

- 1 sharps, 1 soft and 1 organic waste container with well-fitting lid, well attached.

Sharps

- Provide appropriate sharps containers in convenient locations (next to the examination table, on a tray or trolley for mobile use in the wards):
 - Modified drugs pot / commercial sharps container (or reusable sharps container if available; in adapted quantities); if lots of empty ampoules and vials are generated, a separate glass container can be provided, for them to be crushed afterwards in a safe glass crusher.
 - Safety box: in case of immunization or for specific waste (e.g. very long needles), possibly also in the early stages of an acute emergency (latter to be avoided).
- Ensure the regular collection and disposal of sharp waste.
- Provide an appropriate sharps pit:
 - Concrete lined (sealed) pit or adapted drum / plastic container in case of acute emergency, small health post, starting up phase of bigger structures, slum where there isn't space to construct a concrete sharps pit.
 - With a Safety Box Reducer if this kind of containers is used in the structure.
 - With a glass crusher if lots of glass waste is generated.

Soft waste

- Provide appropriate soft waste containers (plastic buckets of 20 - 60 l capacity with lid, all of the same colour) in convenient locations (next to the examination table, on a trolley for mobile use in the wards).
- Ensure at least daily collection of the soft waste, with safe temporary storage before (potential) treatment.
- Ensure disinfection and cleaning of the emptied soft waste containers.
- Provide appropriate treatment and/or disposal facilities:
 - Acute emergency:
 - Drum volume reducer and residues (ash) pit.
 - Ashes and residues deposited directly in the ash / residues pit.
 - Chronic emergencies and stabilised situations:
 - De Montfort incinerator (or equivalent) with 2 ash / residues pits.
 - Ashes and residues deposited directly in the ash / residues pit.
 - Covered pit (without former treatment), but only if a (very) small quantity of waste is generated and/or a lot of space is available.
 - Exceptionally, offsite disposal with appropriate transport facilities (e.g. containers, vehicles, waybills) if urban zone / dense population / no space.

Organic waste

- Provide appropriate organic waste containers (plastic buckets with lid, all of the same colour, but different than for soft waste) in a convenient location (next to the delivery chair, the operating table).
 - Delivery room: 15 to 40 l.
 - Operating theatre: 20 to 60 l.
- Ensure immediate collection and disposal of the organic waste.
- Ensure disinfection and cleaning of the emptied organic waste containers.
- Provide appropriate final disposal facilities:
 - Latrine (for placentas, but only if very few deliveries are done; NOT to be used for body parts).
 - Acute emergency:
 - Organic waste pit (closed pit, or open pit with contents covered with soil).
 - Chronic emergencies and stabilised situations.
 - 2 organic waste pits, each with a fixed cover and a ventilation pipe.
 - Exceptionally offsite treatment / disposal with appropriate transport facilities (e.g. containers, vehicles, waybills) or incineration with fuel feeded high temperature incineration if urban zone / dense population / no space.

Hazardous waste

- Ensure that all hazardous waste is disposed of legally, and disposal practices and methods comply with, or exceed the country legislation.
- Ensure that all hazardous waste is disposed of safely (according to the WHO recommendations). If required, ask advice from your technical referent.

Waste zone

- Provide a defined waste zone with soft waste storage and all appropriate treatment and disposal facilities located inside.
- Install a fence around the waste zone.
- Install a washing area with water point within the waste zone.
- Install facilities for wastewater evacuation via a grease trap to an appropriate disposal system.
- Ensure management and supervision by designated and trained person(s).
- Distance > 50 m from water sources (certainly when organic waste pits are included).
- The complete waste zone must be maintained daily.

Dead bodies

Dead bodies related to war / famine / natural disasters DO NOT represent a major public health risk. A good management is needed however to avoid proximity to the dead (psychological effects), odours and scavengers / vectors. Dead bodies related to epidemics (e.g. cholera, Ebola, Marburg, typhus, plague) DO represent a public health risk and strict rules have to be followed in order to avoid further disease transmission (refer to specific guidelines!).

- Ensure safe storage of bodies prior to burial / cremation:
 - Provide an appropriately sized and located morgue for In-patients structures, with a separate morgue for the isolation units.
- Ensure that dead bodies are handled safely, and that appropriate hygiene and disinfection measures are taken when handling and preparing the bodies.
 - General:
 - All persons handling and preparing bodies wear gloves.
 - All persons handling and preparing bodies wash hands using water and soap after manipulation.
 - Epidemics of contagious diseases (*refer to specific guidelines!*):
 - All persons handling, preparing and burying bodies wear appropriate protective equipment (disease specific).
 - All persons handling, preparing and burying bodies wash themselves within the isolation centre according to the appropriate rules (disease specific).
 - Safe leak-proof containment of bodies; e.g. body bags for cholera, body bags and coffin for Viral Hemorrhagic Fevers (disease specific).
 - Trained team carry out disinfection of bodies, structures and transport facilities.
 - Trained team perform and/or supervise burial (with burial practices to be evaluated in every context).
 - Cremation should only be done on specific demand of relatives and or if specific facilities are available.
 - Ensure that handling, preparation, and burial / cremation of the bodies is done in a culturally sensitive manner.

Control of vectors

- Prevent the transmission of vector borne diseases within health structures.
 - Minimise the survival chance and density of vectors in health structures.
 - Reduce contact of persons (e.g. patients, staff) with potentially infected vectors.
 - Reduce contact of vectors with infected patients.
- Prevent infestation of vectors and nuisance pests in health structures.
- Provide appropriate vector control facilities, equipment and services in addition to the other water and sanitation requirements (see table next page):

T.B. 1.09 Essential water and sanitation requirements in camps

The essential water and sanitation requirements contribute towards reducing water, hygiene and sanitation related diseases within camps (refugees and internal displaced persons). The essential requirements are applicable to acute through to chronic emergencies, until stabilised situations. Within the acute phase of an emergency in camps, the potable water supply and safe excreta disposal are the highest priority within the water and sanitation activities; vector control, wastewater and solid waste management should still start as soon as possible. In order to have a positive effect, the essential water and sanitation requirements should be reached, and preferably even be exceeded. However, the essential requirements are not stand alone standards. They need to be adapted to the context and should be seen as reference points, not as absolute rules. They are means to allow acceptable cohabitation of a big population in a camp from a water and sanitation point of view.

Human-related activities required for assessment, planning, training, and promotion

The essential requirements list mainly technical criteria, but it is clear that no intervention can be considered successful if the facilities are inappropriate for local conditions, if they are incorrectly used, or if they are not maintained (correctly). The human-related activities must go hand in hand with any technical intervention.

Acute emergency	Chronic emergencies and stabilised situations
<ul style="list-style-type: none">■ Initial assessment and analysis■ Technical training to the staff■ Health education to the beneficiaries	<ul style="list-style-type: none">■ Initial assessment and analysis■ In-depth assessment and analysis with the beneficiaries■ General and technical training to the staff■ Health promotion to the beneficiaries

Staff management

Ensure that the staff are trained, equipped, and managed correctly:

- Identify and train the WHS responsible(s).
- Provide the necessary administrative and technical tools:
 - Job descriptions for all staff.
 - Appropriate protective clothing when they are involved in hazardous Water, Hygiene and Sanitation (WHS) activities.
 - Appropriate tools.

Water

Provide adequate and appropriate water supply facilities

The main issues for water supply facilities are their:

- Quality.
- Quantity.
- Accessibility.

Water quality

Provide water of acceptable quality

No pathogens	Free residual chlorine concentration at distribution points <ul style="list-style-type: none"> ■ 0.2 - 0.5 mg/l (if pH < 8) minimum 30 minutes contact time ■ 0.4 - 1.0 mg/l (if pH > 8) minimum 60 minutes contact time or max 10 E.Coli/100 ml at discharge points if chlorination is really not possible
Low turbidity	<ul style="list-style-type: none"> ■ < 5NTU ■ < 20NTU is permissible in an acute emergency
Low concentration of compounds that are acutely toxic or that have serious long-term effects	Context specific; in case of doubt, contact your technical referent
Acceptable to the users	<ul style="list-style-type: none"> ■ Water not rejected due to colour, taste, odour or salinity

Regular surveys done at all water points

Water quantity and accessibility

Provide adequate quantities of accessible and reliable water

Scenario	Quantity/ person/day	Max. distance to source	Min. storage capacity and distribution
Acute emergency: first days	3 – 5 l	No max. distance	<ul style="list-style-type: none"> ■ Min. collective storage capacity: 5 l/person (so for 1000 persons, a bladder of 5 m³ is needed) ■ Min. household transport / storage capacity: 40 l/household
Acute emergency: as soon as possible	15 – 20 l		
Chronic emergency and stabilised situation	15 – 20 l, but no restriction on quantity	Max. 250 m	<ul style="list-style-type: none"> ■ Distribution: <ul style="list-style-type: none"> → 1 tap/200 - 250 persons → 1 hand pump/500 (- 750) persons

- Keep in mind that up to 20% of the water can get lost through leaks and spillage.
- Water could also be foreseen for the beneficiaries':
 - Cattle: 30 l/animal a day.
 - Small animals (e.g. goats): 5 l/animal a day.

Excreta disposal

Provide adequate and appropriate excreta disposal facilities

In sufficient quantity	<p>Acute emergency</p> <ul style="list-style-type: none"> ■ First days: <ul style="list-style-type: none"> → Defecation field: 0.5 m²/user day (pathways not included) → Trench latrines: 3.5 m/100 users ■ As soon as possible: <ul style="list-style-type: none"> → 1 improved trench latrine/100 users → 1 latrine/100 users => 1 latrine/50 users => 1 latrine/20 users <p>Chronic emergency and stabilized situation</p> <ul style="list-style-type: none"> → 1 latrine/20 users or 1 latrine/4 households (cluster) → Family latrines (preferable for hygiene reasons)
Technically appropriate (depending on local constraints)	<p>Acute emergency</p> <ul style="list-style-type: none"> ■ First days: <ul style="list-style-type: none"> → Defecation fields (arid zones) → Trench latrines ■ As soon as possible: <ul style="list-style-type: none"> → Improved trench latrines / pit latrines <p>Chronic Emergency and stabilised situation</p> <ul style="list-style-type: none"> → Pit latrines → VIP latrines (if people have already experience with these facilities) → (Pour) flush latrines: only if there is: <ul style="list-style-type: none"> • Cultural acceptance / demand • Enough water and recipients availability (for anal cleansing)
Appropriate for the users	<ul style="list-style-type: none"> ■ The facilities must be culturally and socially appropriate ■ Preferably separation between male and female (certainly if it's culturally necessary) ■ Some latrines provided with seats and handlebars for physically impaired persons ■ Some children's latrines (often 1/5 of the population is < 5 years old)
Easily accessible	<ul style="list-style-type: none"> ■ Distance of trench latrines: > 30m and < 50m from dwellings ■ Distance of improved trench latrines / pit latrines: > 5m and < 50m from dwellings
At safe location	<ul style="list-style-type: none"> ■ To avoid risk of sexual violence ■ Night lights provided and operating (if feasible) ■ Guards at defecation fields and trench latrines (also to explain correct use)
Convenient hand washing facilities	<ul style="list-style-type: none"> ■ Soap / ash, hand washing and waste water facilities provided at the exit of defecation facilities
Prevent contamination of water resources	<ul style="list-style-type: none"> ■ Latrines > 30 m away from water sources (> 50 m in case of defecation fields)

All excreta disposal facilities must be maintained regularly (preferably daily).

Wastewater disposal

Provide personal hygiene facilities

In sufficient quantity	<ul style="list-style-type: none"> ■ 2 (bucket) showers or washing facilities/community (about 80 persons)
Appropriate for the users	<ul style="list-style-type: none"> ■ The facilities must be culturally and socially appropriate ■ Separation between male and female (small children can go to the women's showers)
At safe location	<ul style="list-style-type: none"> ■ To avoid risk of sexual violence ■ Night lights provided and operating (if feasible)
Related facilities	<ul style="list-style-type: none"> ■ Water supply close by (maximum 5 to 20 m walking distance) ■ Showers connected to wastewater facilities

Provide washing areas

Separate washing areas for	<ul style="list-style-type: none"> ■ The dishes if kitchens are present: 1 area/community (about 80 persons) ■ The laundry with drying lines (if required): 1 area/community
Appropriate for the users	<ul style="list-style-type: none"> ■ The facilities must be culturally and socially appropriate
Related facilities	<ul style="list-style-type: none"> ■ Water supply close by (maximum 5 to 20 m walking distance) ■ Washing areas connected to wastewater facilities

All personal hygiene facilities and washing areas must be maintained regularly.

Provide soap

The use of soap reduces the transmission of all kinds of diseases, so foresee soap distribution: 250 g per person a month.

Provide adequate wastewater disposal facilities

Type of wastewater	Grease trap	Disposal	Distance between disposal and water resource
Clean" wastewater of water collection points e.g. tap stands, hand pumps (without soap, oil, grease)	No	<ul style="list-style-type: none"> ■ Little vegetable garden ■ Animal drinking trough ■ Soak away pit ■ Infiltration trenches 	> 10 m
		<ul style="list-style-type: none"> ■ Properly sealed sewer system. 	
"Dirty" wastewater (grey water with soap, oil, grease)	Yes	<ul style="list-style-type: none"> ■ Soak away pit ■ Infiltration trenches ■ Evapo-transpiration area (arid zone) 	> 30 m
		<ul style="list-style-type: none"> ■ Properly sealed sewer system 	
Rain and runoff water	No	Natural drainage (to be planned from the start)	

All waste water systems must be maintained at least once per week.

Domestic waste disposal

Provide safe and secure storage and final disposal of all types of waste

	Collective (emergency)	Household (stabilized situation)
Temporary storage	■ 100 - 125 litre drums	■ Waste bin (e.g. bucket)
Collection	■ Teams	■ Household member
Transport	■ Cart / vehicle	■ By hand
Treatment	■ Not recommended	■ Not recommended
Final disposal	■ Controlled tip	■ Domestic refuse pit

In emergencies, it's often easier for the aid-agency to install a collective system, because the household system demands a good training and collaboration of the beneficiaries, which might be difficult to obtain, especially in the initial phase. However in the long run, a household system is cheaper and more "sustainable".

Collective domestic waste management system

Temporary storage	Collection and transport	Final disposal
<ul style="list-style-type: none"> ■ 2 bins/community (about 80 persons) ■ Lid on the drums (to avoid dispersion by wind and animals) 	<ul style="list-style-type: none"> ■ Establishment of circuits ■ Constitution of teams (2.5 persons/1000 inhabitants) ■ Allocation of circuit to each team ■ Daily collection 	<ul style="list-style-type: none"> ■ Controlled tip ■ > 800 m from dwellings ■ Fenced ■ Evacuation of runoff water

Household domestic waste management system

Temporary storage	Collection and transport	Final disposal
<ul style="list-style-type: none"> ■ 20 litre bucket with lid per household 	<ul style="list-style-type: none"> ■ Good practice of population required, thus need for: <ul style="list-style-type: none"> → Training → Discipline 	<ul style="list-style-type: none"> ■ 1 pit/household or several households ■ Need for a fence ■ Waste covered (soil or lid) after each disposal ■ Need for the population to re-dig a hole when the old one is full

Dead bodies management

Dead bodies related to war / famine / natural disasters DO NOT represent a major public health risk. A good management is needed however to avoid proximity to the dead (psychological effects), odours and scavengers / vectors. Dead bodies related to epidemics (e.g. cholera, Ebola, Marburg, typhus, plague) DO represent a public health risk and strict rules have to be followed in order to avoid further disease transmission (refer to specific guidelines!).

	War / Famine / Natural disaster	Epidemics (cholera, haemorrhagic fevers)
Body preparation and dressing	<ul style="list-style-type: none"> ■ No disinfection of body needed ■ Body dressing depending on local customs and/or availability: coffin / shroud (cloth) / blanket / sleeping mat / body bag 	<ul style="list-style-type: none"> ■ Disinfection of the body (disease specific; according to the specific guidelines) and ■ Sealed body bags + (coffins; disease specific)
Burial / cremation procedures by:	<ul style="list-style-type: none"> ■ Relatives ■ Aid-agencies potentially in case of mass burial 	<ul style="list-style-type: none"> ■ Trained and protected personnel of the aid-agency due to the very high contamination risk: <ul style="list-style-type: none"> → Disinfecting the body, living environment, health structure → Burial team (at least supervision)
Personal protection	Hand washing with soap	According to the specific guidelines related to the diseases <ul style="list-style-type: none"> ■ Complete spraying of the staff with a chlorine solution ■ Complete protective gear for staff
Other help from aid-agencies	Providing / involved in (if needed): <ul style="list-style-type: none"> ■ Morgue in health structure ■ Selection of the burial / cremation site ■ Body dressing material ■ Potential transport of the bodies 	Providing / involved in: <ul style="list-style-type: none"> ■ Morgue in the isolation centre ■ Selection of the burial site ■ Sealed body bags / impervious wrappings ■ Transport of the bodies

Ensure that the handling, preparation, and burial / cremation of the bodies is done in a culturally sensitive manner.

<u>Burial</u>	<u>Cremation</u>
Preferred option in all situations	Only when strictly demanded by the population for religious / cultural reasons
Burial site: <ul style="list-style-type: none"> ■ > 50 m away from potable water resources ■ > 500 m away from the dwellings ■ 1500 m²/10.000 inhabitants ■ Graves: <ul style="list-style-type: none"> → Preferably individual graves → Mass graves if really necessary (but trenches for people to be buried head to toe) ■ Respect local customs: <ul style="list-style-type: none"> → Orientation of the graves → Position of the body in the grave → Separate burial areas for different religions 	Cremation site: <ul style="list-style-type: none"> ■ > 500 m away from the dwellings ■ Downwind of the dwellings
Burial depth: <ul style="list-style-type: none"> ■ > 1.5 m under the surface ■ > 1.5 m above the highest possible water table (rainy season) 	Needs: <ul style="list-style-type: none"> ■ At least 300 kg of firewood per body ■ Experienced people for the cremation

Control of vectors

Provide appropriate vector control facilities, equipment, and services

- Prevent transmission of vector borne diseases within camps:
 - Minimise the survival chance of vectors in camps.
 - Reduce contact of population with potentially infected vectors.
 - Reduce contact of vectors with infected persons.
- Prevent infestation of vectors and nuisance pests in the camp.
- Provide appropriate vector control facilities, equipment and services in addition to the other water and sanitation requirements (see Table hereunder).

Common vectors	Common diseases	Measures to take for endemic zones and/or high presence of the vector							Extra measures to take during outbreaks									
		Proper site selection	2 X IRS* of all dwellings/year	2 X IRS of all latrines/year	1 LN*/sleeping place	Limit vector breeding sites in and around camp	Fly traps and/or screens	General food hygiene	Airing bedding in sun	Promote 2 X per day face and hand hygiene for entire camp	Poison and/or trap and dispose of rats	Insecticidal dusting of incoming persons	Larviciding** and/or promote emptying stagnant water every week	Space spraying 300 m around dwelling of confirmed case	Follow-up insecticidal dusting on request	1 X insecticidal dusting mats, bed frames, clothes in dwellings	Insecticidal dusting of corpses and deceased clothes	Promote absence of animals in dwellings
<i>Anopheles</i> mosquitoes	Malaria	X	X		X	X												
<i>Aedes</i> mosquitoes	Dengue, Yellow Fever	X	X			X						X	X					X
Flies	Enteric infections	X	X	X		X	X	X										
Flies	Eye infections	X	X	X	X	X	X		X									
Sand flies	Leishmaniasis	X	X		X	X												
Lice	Typhus, Relapsing Fever, Trench Fever		X		X						X			X	X	X		
Fleas	Plague, Typhus		X		X			X		X	X			X	X	X	X	
Rodents	Lassa fever, Salmonellosis, Leptospirosis, Plague, Hanta Fever	X						X		X								
Mites	Scabies				X													

*IRS: Insecticide Residual Spraying; LN: Long-Lasting Insecticidal Net.

** : Only when skilled personnel is available.

T.B. 1.10 Site planning of camps

A large influx of people to a site requires the rapid installation of infrastructures, which meet the priority needs of the population. The health status of refugees / displaced persons depends directly on the operational capacity of those responsible for their protection and assistance. Proper selection and planning of an appropriate site will make sure that good infrastructures can be achieved and that the camp is situated in an environment that does not have a negative impact on people's health.

Procedure

Having chosen the site according to key criteria (T.B. 1.05), there are a series of decisions and specific activities that need to take place:

- Prepare a map of the site including amongst others the water resources, the existing defecation areas, the surface drainage patterns, the available space for a cemetery and potentially a controlled tip.
- Determine the needs for services and infrastructures, based on the estimated population size.
- Define the size of the camp and its sub-divisions to facilitate camp management.
- Design the camp layout.
- Define the responsibilities in the camp (e.g. which aid-agency is in charge of water supply).
- List the resources needed (budgetary, logistic, human) according to the respective responsibilities taken by the aid-agencies.

Mapping

In order to see how much land is available, it's important to have a map of the available site. One way of obtaining this map is by the mapping method (T.B. 1.02.). In this stage, it might be interesting to have a map with a bigger scale than 1/10,000 to be able to indicate more details. Information on the slopes of the camp can be obtained by doing a topographic survey (T.B. 2.24). As such, the map will also be an interesting tool for the camp design.

Needs

Listed below are the service and infrastructure needs that are common to most camps:

- Water and sanitation facilities; a priority issue when designing the layout.
- Roads.
- Warehouses, food distribution points.
- Shelter (type and number).
- Administrative structures (e.g. screening, registration).
- Medical and nutritional feeding structures.
- Personnel accommodation.
- Community facilities (e.g. market, cultural centre, workshops, schools, religious structures, recreation grounds).

Size definition

The size of the camp will depend on the available space of the selected site. But it's preferable not to make too big camps for management purposes, even if the availability of space would permit it. Ideally, a camp should host maximum 20,000 people in subdivisions of 5,000 persons. Be aware that the site should also offer space for firebreaks, a separated cemetery and landfill. Additional space should be preserved for a potential extension of the camp.

Area available/person	: 30 m ² (including area for dwellings, firebreaks, storage, administration, market, dispensary, cemetery, landfill) : 45 m ² (if small vegetable gardens are required additionally)
Dwelling space/person	: 3.5 m ² (4.5 – 5.5 m ² in cold climates)
Firebreaks	: 30 - 75 m strip every 300 m

Camp Design

All the necessary structures / facilities should be added to the initial map and the way that shelters are to be grouped decided. This decision will eventually affect the correct use of latrines and water points. Security for the population and re-establishment of its social fabric should also be considered when deciding on the shelter layout.

Water and sanitation facilities

Water and sanitation facilities are a priority issue when designing the overall layout of a camp. In case the water resources are located inside or nearby the camp site, it is important to protect them from (further) contamination; correct locations of the water intakes and the evacuation places of runoff water.

Latrines, showers and washing facilities should be located at places that won't contaminate the water resources, but not too far and too isolated either in order to prevent sexual violence. These places should preferably be well lighted at night. A landfill and cemetery / cremation site will have to be located at appropriate places as well: away from water resources, and at a minimum distance and downwind from camp dwellings and potential population housing.

Additional information on water and sanitation facilities within camps can be found in T.B.1.06 and 1.09.

Roads and direction signs

The road system within the camp should be organized according to the structures / facilities that should be easily reachable and according to the shelter layout. In order to preserve their condition, the roads should have a drainage system which should be connected to the general drainage system of the camp.

Direction signs / logos are also important within the camp: they should enable the easy identification of zones with different activities and of each residential area, for visitors as well as for residents. Signs / logos should be understandable for everybody, given that not everybody knows how to read or masters international as well as local languages. For large camps, a detailed plan placed at the entrance may be necessary.

Shelter lay out and type of dwelling

Several blueprints for shelter layout exist, but the cultural habits of the population concerned should be the guiding principle.

Avoid layouts in lines and rows; they increase distances from dwellings to latrines and water points. On the other hand, this method can be implemented quickly and it is better than no planning at all. Give preference to a shelter layout per community unit, without separating families. The basic community unit is formed by grouping 16 shelters in a square or rectangle around a communal space. Latrines, water points and washing areas may be placed around the community unit. Spaces for community facilities and services are created by leaving out a number of basic units according to the space required.

Distance between two tents / shelters	: 2 m minimum, but preferably twice the size of the overall height of the shelters (to avoid damage when a neighbouring shelter collapses), or even 3 – 4 times the height if the shelters are made from highly inflammable material (straw, thatch)
Distance between two rows	: 10 m

Tents are often used in the initial phase. Apart the fact that they do not last long, they are expensive to buy and to transport. It is often more feasible therefore, to use locally available construction materials (e.g. planks, corrugated iron sheets). While more durable dwellings are being built, plastic sheeting may be stretched over ropes and poles for temporary shelters.

Energy and lighting

Energy is needed essentially for cooking food, but sometimes also for heating. Wood is often the most commonly used energy source, but it may be logistically difficult to supply it. And it involves politico-ecological problems because of deforestation.

Lighting is desirable in the camp as a whole because it reduces insecurity and allows better access to sanitary facilities. Take into consideration however that the installation of an electricity supply system in the camp may cause safety problems (e.g. illegal connections), as well as troubles with the local population if they do not have access to electricity (which is often the case). Electricity is indispensable though in health centres open at night like an isolation ward, a Cholera Treatment Centre (CTC) and an In-patient Therapeutic Feeding Centre (ITFC).

Responsibilities

The selection and general planning is normally done by the official authorities (e.g. UNHCR, local authorities), but involvement of Non-Governmental Organisations (NGO) is recommended. The selection and planning of a site should preferably be done by a multi disciplinary team that consists of a medical person, a logistician and a water, hygiene and sanitation technician / engineer.

Besides the general planning, it will have to be decided what will be the respective responsibilities of each aid-agency regarding the installation of the different services and infrastructures to respond to the different needs of the beneficiaries. The aid-agencies should be accountable for the engagements taken.

Resources

According to the responsibilities / engagements taken, budgetary, logistic and human resources will be needed. These could be defined by means of the logic framework, which is an interesting tool in the strategy planning.

Remarks

- In the initial phases of the emergency, it is very hard to gauge, with any confidence, the likely duration of the camp. Therefore it is best to select, plan and install the site within the briefest delay possible. However, as the camp may remain for many years, a long-term view is recommended.
- To avoid becoming overtaken by the events later, it is important to establish short and medium-term plans from the beginning, allowing for a probable population increase.
- Coordination in between the different aid-agencies (e.g. UN, Red Cross, international and national NGO's) and potentially the national and community authorities is of utmost importance in the planning, implementation and running of a camp.
- Where possible, encourage the involvement of women and men in the planning of the site.
- Site planning has very often to be done for a camp which is already established. Therefore it becomes a job of reorganization. This is much more difficult to achieve due to problems in doing topographical surveys because of congestion, in overcoming reluctance to change from the beneficiaries and the aid teams.
- In case a reorganization of the camp is necessary, it is recommended to do this section by section. To do so, a new plot of land with the correct size of a section should be available and prepared, prior to moving the population of a first section. The liberated space they have left behind them can then be reorganized and prepared for a second section to move, and so on.



Water Supply

Narrative

Technical briefs

- T.B. 2.01 Water intakes
- T.B. 2.02 Description of a hand dug well
- T.B. 2.03 Cleaning and disinfection of a well
- T.B. 2.04 Protecting a shallow well
- T.B. 2.05 Mortar and concrete preparation
- T.B. 2.06 Fabricating concrete rings
- T.B. 2.07 Jetting
- T.B. 2.08 Protecting a spring
- T.B. 2.09 Rainwater harvesting
- T.B. 2.10 Water analysis
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- T.B. 2.13 Turbidity measurement
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- T.B. 2.22 Monitoring chlorination
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- T.B. 2.37 Cleaning of flexible reservoirs
- T.B. 2.38 Ferrocement tank
- T.B. 2.39 Distribution tapstand

Chapter 2

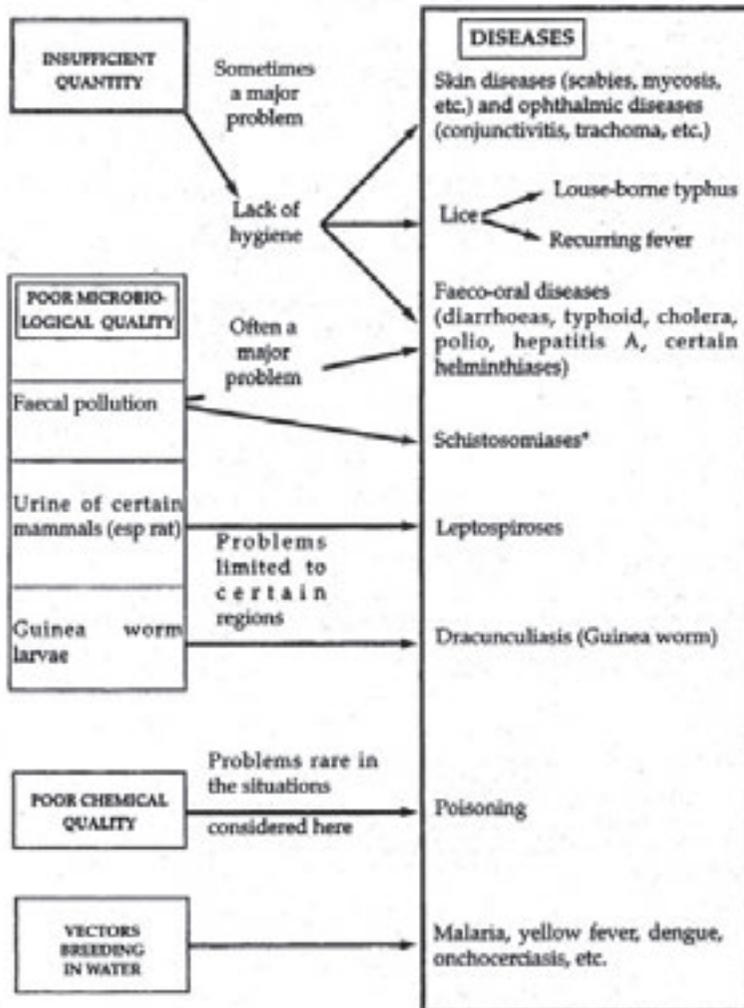


2.1 Why is water important to human beings?

Water is indispensable for human life, in adequate quantity and quality. Without water, human beings cannot live for more than a few days. It plays a vital role in nearly every function of the body. But besides being a vital element of (public) health and well-being, water is also related to most of human activities. Also, a health structure cannot function properly without a reliable source of clean water.

Water is often also related to quite some health problems, so appropriate attention should be given to it.

Water related health problems



* In schistosomiasis caused by *Schistosoma haematobium*, transmission occurs via urine and not via faeces.

Water related infectious diseases can be classified according to their transmission routes:

- **Water-borne diseases:** caused by the ingestion of water containing pathogenic micro-organisms. Water can be a transmission route of certain diseases when it has been contaminated by faeces or urine of human beings or warm-blooded animals. But some of these diseases may also be transmitted by any of the other faecal-oral routes like dirty hands and contaminated food, which are grouped in water-washed diseases.
- **Water-washed diseases:** due to lack of proper domestic and personal hygiene. Insufficient water supply is one factor leading to improper hygiene. The diseases linked to lack of water for hygiene are:
 - **Faecal-orally transmitted diseases:** lack of hygiene, particularly of hands and food, allows the transmission of these diseases from infected individuals and animals (sick or healthy carriers) to uninfected individuals. This results in the so-called “dirty hands diseases”.
 - **Dermatological and ophthalmic diseases:** lack of personal hygiene can lead to skin and eye infections.
 - **Diseases transmitted by lice:** lack of personal hygiene and washing of clothes encourages the proliferation of lice which, in addition to the problems caused by their presence (itching and scratching, skin sores), are disease vectors.
- **Water-based diseases:** their causal agent (pathogen) has to pass part of its life-cycle in an intermediate organism (host) that is living in the water.
- **Water-related insect vector diseases:** are related with an insect vector which develops in or lives near water.

2.2 What is a safe water supply?

A safe water supply has the objective to ensure the **access** of the consumers to correct **quantities** of good **quality** water.

2.2.1 Quantity

In tropical climates, the daily minimum volume of water required for survival (drinking and cooking) would be around 3 to 5 litres per person a day, because the human body needs a minimum intake to sustain life before mild and then severe dehydration occurs. It is estimated that 2.6 litres of water per day is lost through respiratory loss, (insensible) perspiration, urination and defecation. In addition, a significant quantity of water is lost through sensible perspiration if hard work is performed.

The need for domestic water supplies for basic health protection exceeds the minimum required for survival. Additional volumes should be foreseen for maintaining domestic and personal hygiene through food and hand washing, bathing and laundry. Therefore should the survival quantity be increased as soon as possible because insufficient water quantities will induce poor hygiene, which in turn will cause all kinds of water-washed diseases. Domestic water supply should thus be minimal 15 to 20 litres per person a day (T.B. 1.09). Where possible, it is better not to put any limit on consumption as the health status of the population is influenced by the quantity of water used. The quantities of water used worldwide depend on many variables and cultural practices.

In the first phase of an emergency, it is preferable to have a lot of water of average quality than a little amount of water of very good quality. As soon as possible, high quantities of good quality water must be delivered however.

Besides the water needed by the population itself, additional water might be necessary for special needs like cattle (e.g. 30 l per animal a day) and certainly to cover the losses due to leaks and spillages (up to 20 %).

Health structures including inpatients and outpatients departments, and specific health facilities such as cholera treatment and feeding centres will always require considerable amounts of water of good quality, even in acute emergencies (T.B. 1.08). When these essential water requirements can't be reached, the correct functioning of the health structure will be jeopardized. In later phases of emergencies and in stabilized situations, the water quantities should be increased because the water demand will most probably rise (improved medical activities, but also more “domestic” activities by and for the patients and their visitors, such as showering and doing the laundry).

According to the needs, it is important to evaluate the amount of water that can be supplied to cover those requirements. The objective should be to secure water sources that provide more water in 24 hours than the strict daily volume required for the targeted purpose. In health structures, it is strongly recommended to have a reserve storage capacity lasting for at least two days in order to cope with a water supply failure.

2.2.2 Quality

For water to be potable, it must have following characteristics:

- Contains no pathogens (good microbiological quality).
- Contains no or only a harmless concentration of toxic chemical products.
- Has a low turbidity.
- Has a low salinity.
- Has no taste, colour or odour (smell).
- Is not corrosive and doesn't favour encrustation.

One has also to keep in mind however that there is no direct relationship between the appearance of a water sample and its drinkability (a cloudy sample may be safe, whereas a clear sample may be both chemically and biologically dangerous).

Microbiological quality

Water can be the cause of diseases, which can spread epidemically in a (concentrated) population. Five categories of pathogens can be found in water: bacteria, viruses, protozoa, helminths (eggs) and fungi. Water contaminated with (one of) these biological elements can cause a variety of communicable diseases through ingestion or physical contact. The potential consequences are such that microbial contamination control is always of paramount importance and can never be compromised (T.B 2.10).

Chemical quality

Chemical contaminants present in the water might have been introduced naturally, caused by the geological structure of the underground, or man-made due to (intensive) agricultural and industrial activities. Removing chemicals from water often proves to be an expensive and very difficult task. The choice of the water source will therefore be of utmost importance.

The chemical quality of drinking water can have a direct health implication, due to the absence of necessary chemical constituents (although very rare) or by the excessive presence of certain chemical elements. This is a rapidly increasing problem in low-income countries. Most of the human intake of chemicals occurs through the food, not via the drinking water however.

The health risk due to toxic chemicals in drinking water differs from that caused by microbiological contaminants. The problems associated with chemical constituents at a low concentration within drinking water arise primarily from their ability to cause adverse health effects after prolonged periods (years) of exposure. High concentrations of chemicals in the potable water supply, and certainly massive (accidental) contamination can cause serious (acute) health problems.

The chemical contaminants (T.B 2.10) can be harmful organics like pesticides or harmful inorganic products such as:

- Arsenic: which is widely distributed throughout the Earth's crust, and of great concern for instance in Pakistan and Bangladesh as it is carcinogenic.
- Fluoride: which is an element of importance in eastern Africa. A high concentration carries an increasing risk of dental fluorosis, and can lead to skeletal fluorosis.
- Mercury: which presence should be suspected in areas where gold extraction is carried out. It is a toxic heavy metal.
- Nitrates: which are introduced by over-fertilizing or due to high amounts of excreta (mainly urine) being disposed of in very dense population settings (e.g. a refugee camp). A relatively low concentration of nitrates can already cause methaemoglobinaemia in newborn babies (blue-babies disease).
- Nitrites: which is a reduced form of nitrates can be introduced by backfilling wells with termite hills and can lead to immediate death.

Control measures for water related infectious diseases

Diseases	Water-washed				Water-related insect vectors
	Water-borne	Faeco-oral	Skin / eye infections	Lice related	
	Cholera Dysentery Giardiasis Hepatitis A Polio myelitis Typhoid fever	Cholera Diarrhoeas Dysenterias Hepatitis A (Para)typhoid fevers Pollomyelitis Various helminths diseases	Scabies Conjunctivitis Trachoma	Louse-borne typhus Recurrent fever	Bilharzias Dracunculosis (Guinea worm) Malaria Dengue Yellow fever
Control measures					
Improve water quality: source protection, water treatment	X	-	-	-	X
Increase water quantity	-	X	X	X	-
Improve water accessibility	X	X	X	X	-
Reduction of the contact with the infected water	-	-	-	-	X
Improve the environmental sanitation: latrines, drainage, waste (water) elimination	X	X	-	-	X
Choice of settlement site	-	-	-	-	X
Correct household water storage: quality / quantity	X	X	X	X	-
Improve personal hygiene	-	X	X	X	-
Improve food handling and preparation	-	X	-	-	-
Use of pesticides	-	-	-	X	X e.g. snail control
Personal protection (e.g. bed nets)	-	-	-	X	X
Health promotion	X	X	X	X	X

Turbidity

This characteristic is a measure of the amount of suspended particles in the water (T.B. 2.13). The turbidity of water is mainly of importance because it inhibits the effectiveness of disinfection (T.B. 2.13 and 2.21) and hence the correct microbiological quality of the water. Turbidity will also directly affect the acceptance of the water by the consumers.

Salinity

Salinity is a measure of the amount of dissolved salts in the water which should be low for the acceptability of the consumers, and to avoid corrosion of the equipment. A high salinity concentration can also cause negative health effects such as diarrhoea, vomiting and renal failure.

Colour, taste and odour (smell)

Colour, taste and smell are characteristics due to the presence of some micro-organisms and/or chemical substances in the water.

Corrosion and encrustation

Corrosion can also be caused by the high acidity (low pH) of the water, and encrustation is due to certain minerals (e.g. calcium carbonate). Both may affect the longevity of equipment (e.g. pipes, pumps). The pH also has a serious influence on water treatment procedures (e.g. coagulation / flocculation, chlorination). The chemical water quality and/or the above mentioned characteristics may affect a consumer's acceptance to drink that particular water, therefore turning to more palatable but potentially biologically unsafe water from a contaminated source. As such, these factors can also become an indirect health hazard.

2.2.3 Accessibility

Efforts to obtain sufficient water quantities of correct quality are ineffective if the beneficiaries don't have a rather easy and nearby access to it. The further the distance in between the water discharge / distribution point and the beneficiaries living area, the less water they will collect. In case water has to be paid for, it will probably reduce the amount of water that is collected. To avoid problems of long queuing, which could result in aggression, enough water points should be foreseen. Besides the installed procedures and facilities to get the water unhampered in quantity and quality to the beneficiaries, correct transport and storage recipients at household level are essential as well.

2.3 Where/When should a water supply system be implemented and by Who?

2.3.1 Water supply for patients

Whatever the context, water is essential for the functioning of a health structure. From the start, even in acute emergencies, it will be crucial for the aid-agency to provide the required quantities of high quality water (T.B. 1.08). In case good quality water sources aren't available on the spot, water trucking and/or appropriate treatment procedures will have to be implemented. In stabilized situations, the preferred choice would be water sources requiring as little as possible external interventions such as treatment involving chemicals, with the possible exception of chlorine since its use is always recommended to disinfect water in health structures.

2.3.2 Water supply for populations

Water is needed in all places where people are living, such as camps, urban and rural areas. The choice of the water sources and of the actors involved in managing the water system is very much context related. In practice, there is rarely a wide choice between different water sources, particularly in (the first phase of) emergency situations.

Population in an acute emergency situation

In the acute phase of an emergency, the main concern will be to provide enough clean water to the beneficiaries. Therefore, if there is no available supply of good quality water (e.g. town water supply, spring, borehole), the fastest way to extract water is usually to take surface water, and then to treat it. Be sure however that the surface water is of sufficient quality in order to be treatable. In order not to diminish the quality of the surface water by human actions, the first step is to foresee a protected drinking water collection area upstream of dirty activities (e.g. laundry, personal hygiene), and a zone for animal watering downstream. Often in emergencies, aid-agencies might have to support or install and run the water chain.

Population in a chronic emergency / stabilized situation

Once the situation starts to stabilize, the investigation for a better quality and/or a more reliable water source (like groundwater) should begin. The beneficiaries should be involved in this process as well. It might also be important to provide water not only to the people affected by the emergency, such as the refugees, but also to the host population.

For all the scenarios described above, it is strongly recommended to verify always if there are potential local partners, such as national NGO's, water companies, municipal water supplies or water committees. They can be of help for instance in indicating existing water resources, in providing water, in monitoring water quality, and be involved in operation and maintenance follow up.

When a new water source is put into service and if the infrastructures are available, water sampling and analysis should be undertaken by the appropriate (national) authorities, according to the national standards. In this way, the local government will be involved in the process and the responsibility transferred to them. In acute emergencies however, this procedure might be more complicated.

2.4 How to set up a water supply system?

2.4.1 Planning and organisation

For correct planning and organisation of a water supply system, it is necessary to follow all the different steps described in chapter 1, even for acute emergencies.

As water is essential for human survival and the good functioning of a health structure from the very first phase of an emergency already, only simple and rapid (often temporary) water supply solutions should be chosen in the beginning. An initial assessment to collect some basic data on the demography, the practices of the population (e.g. where and how do they collect water and where do they defecate, do they have a private water source), the physical nature of the site, the available water sources (and their capacity to respond to the needs) and the available material are sufficient to determine the acute emergency strategy. The first implementation priority will be to protect the source from (faecal) contamination, with amongst other basic means, the installation of simple defecation facilities (T.B. 3.01, 3.02 and 3.03) far enough from the water source. In case the water storage capacity of the users would be insufficient, recipients should be provided immediately as well.

Within days, it should be possible to augment the water availability by setting up a basic supply system with increased protection of the water source (possibly more than one at this stage), potential treatment (at least chlorination), reservoirs and distribution points. As the situation changes daily, the monitoring will be essential to adapt the system rapidly to the actual needs. The first evaluation should have as an objective to look if the time has come to install less vulnerable systems.

Chronic emergencies and stabilized situations often demand less vulnerable water supply systems. This means that a lot more information needs to be collected and analyzed (e.g. topographic survey, T.B. 2.24) during an in-depth assessment before the strategy can be completely developed. As there isn't a real urgency (anymore), a lot more time and care can be spent on the implementation, monitoring and evaluation of the complete water supply system.

Whatever the context, the chosen strategy will depend largely on the selected water source. Three potential drinking water sources can be distinguished: surface water, groundwater and rainwater.

Surface water

Water that does not infiltrate into the ground is called surface water. As the water flows at the surface, it is exposed to all kinds of microbiological, chemical and physical contaminants, which may be harmful to humans. All surface water is considered to be contaminated unless proven otherwise. Common types of surface water include runoff water, rivers, streams, lakes, and swamps. Because of its easiness to locate and to access, it is often the primary water source in acute emergencies. This doesn't mean however that other water sources shouldn't be considered from the start as well

Water running in the top layers of the soil are also considered as surface water, because the filtration process through the soil has not been completed. An arbitrary limit of 3 meters is usually considered as the limit between surface and groundwater. Even if a river is dry, there may be an important quantity of surface water underneath the river bed.

Groundwater

Groundwater is water that is stored in porous underground layers, called aquifers. Most groundwater originates from precipitation that soaks into the ground. Generally the groundwater will progress in the direction of the oceans, either by movement through the ground or by flowing out (becoming surface water) and joining rivers or streams.

Groundwater is found in most parts of the world and can be a reliable source of drinking water. It is generally free from microbiological contamination, if it is protected correctly and no contamination sources are in the neighbourhood. However, groundwater can pick up minerals from the underground, which have a potential influence on the correct chemical and physical quality of the water. For deep groundwater, there is a lower seasonal flow variation than for surface water.

A well is a hole that pierces an aquifer so that groundwater can be pumped or lifted out. Usually, the hole that pierces the aquifer is called a *hand dug well* (T.B. 2.01; 2.02) if it has been excavated manually, and a *borehole or tube well* if it is made with special equipment (e.g. drilling rig, jetting; T.B. 2.07). Capitalize as much as possible on local knowledge for the right localisation of a new well and/or ask advice to your technical referent. Protecting a well is of utmost importance to avoid its contamination (T.B. 2.04).

Springs and seeps may be the resurgence of groundwater. These sources are interesting as they often combine good microbiological water quality with reasonably easy access. The protection of springs will be of prime importance to avoid its good quality water getting contaminated (T.B. 2.08). An inconvenience of springs might be their variable water yield over the different seasons, or they may even dry up completely.

Precipitation (mainly rainwater)

Rainwater in non-industrialized and non-urban areas presents good quality characteristics. It may represent an important source of water, although its variability in quantity over the seasons is important. Rainwater can be collected from any clean surface, with roof catchments being used most often. The contamination of harvested rainwater comes primarily from the first rains, rinsing away the accumulated dirt on the roof. Correct techniques of rainwater harvesting will remove this contamination first (T.B. 2.09) before the water is stored in reservoirs (e.g. T.B. 2.38) that potentially need to be (very) big.

Table 2.1: comparison between advantages and disadvantages of the different water sources

	Advantages	Disadvantages
Surface water	<ul style="list-style-type: none"> • Relatively big quantities • Easier extraction • Easy to discover 	<ul style="list-style-type: none"> • Usually contaminated, and to be considered as unsafe • Always need for treatment
Groundwater*	<ul style="list-style-type: none"> • Generally of good microbiological quality if correctly protected 	<ul style="list-style-type: none"> • May be subject to chemical contamination • Needs to be extracted, except for springs
Precipitation (rainwater)	<ul style="list-style-type: none"> • In rural areas, it is of drinking quality if correctly collected • Easy to collect 	<ul style="list-style-type: none"> • Very important variability in quantity • Needs big storage capacity to cover dry periods

* An aquifer less than 3 m deep has the characteristics of surface water.

All water sources can potentially be taken into account for water supply, possibly even a combination of different ones. It is always better to use non-polluted water than to try to treat polluted water. But it is useless to focus on water quality alone if all other faecal-oral transmission routes are open: e.g. excreta is scattered everywhere and flies have unhindered access to food.

Operation and maintenance procedures are often forgotten when a water supply system is installed. This should already be taken into consideration when the water source is chosen, certainly if the beneficiaries (water committee) will have to operate and maintain the system themselves. Surface water will always demand a treatment and a distribution system, thus intense operation and maintenance will be required. But also a protected well with a hand pump needs operation and maintenance, as well as a protected spring, certainly when it's connected to a water distribution system. People responsible for the maintenance should be trained, and a system providing sufficient consumables / spare parts should be installed.

2.4.2 Technical process

The consumption of sufficiently clean and safe water can only be achieved by actions at all levels, with global activities on water supply, sanitation (e.g. safe excreta disposal) and health promotion. Pollution at the source and/or during the collective transport can be more dangerous than contamination of the water at home, because it affects the whole population at once and consequently encourages large scale epidemics.

To ensure that the quality characteristics of drinking water are obtained and/or preserved from the source until it is consumed, several technical steps might need to be integrated within the water supply system. Where people take water immediately from a safe source, like for instance from a protected well with a hand pump, the number of technical steps is reduced. But for surface water that needs treatment and that is located away from the beneficiaries, different technical steps will be needed to get it safely to the consumers.

Intakes

Intakes are wells and boreholes, but also collection boxes and pipes through which water from springs, rivers or lakes enters a water supply system and goes either to treatment and/or storage, or in some of the cases, directly to the users. Infiltration galleries are an interesting alternative, except for acute emergencies given the time and expertise that are required for their construction (contact your technical referent). Water moves through the intake either by gravity, either it has to be lifted (T.B. 2.01). It is an important stage because it has to be well designed to avoid loss and (further) contamination of the water. Source protection (T.B. 2.04; 2.08) is nearly always the best and simplest method of ensuring safe drinking water and has to be preferred over treatment of contaminated water. It is important to avoid pollution of the water source by providing latrines, bathing areas and animals watering places at the correct location, thus downstream / downhill of the intake. Surface water can be made more accessible and treated to a certain extent by means of shallow wells, infiltration galleries and the diversion of rivers.

Water Treatment

The main objective of water treatment in precarious situations is the elimination of microbiological pathogens. Several principles exist: proper boiling, appropriate filtration methods, UV-radiation (solar or lamps) and chemical disinfection. For the pathogen elimination to be effective, certain of these principles will require the removal of the particles in suspension (turbid water) first. The main turbidity reduction principles used in emergencies are (assisted) sedimentation and/or filtration. All the above mentioned principles have their specific advantages and disadvantages (T.B. 2.12).

For health structures and closed settings, the treatment will mainly be done on a centralized level. Be aware that treated water can potentially be dangerous in case there is a (hidden) failure in the treatment system. For open settings, household treatment would be ideal, but the (rapid) distribution of equipment and/or supplies to the population needs to be planned carefully. Another difficulty (certainly in emergencies) is the correct usage of the household treatment method, therefore needing an intense promotion campaign to provide the essential knowledge and skills, and to do a close follow up. For these reasons, semi-centralized systems like bucket chlorination (T.B. 2.23) are sometimes set up during (acute) emergencies in open settings.

Water Transport

In case the water source isn't nearby the beneficiaries, it will have to be transported where the people are based. In a first instance, water can be carried with tanker trucks (T.B. 2.34). This system can be set up rapidly and can be very effective. However, it is usually the most expensive way in delivering water, and should only be considered in the very first phase of an emergency (few days or weeks).

Although it might take some time to install, a piping system to carry the water over reasonable distances (some km) should be considered. Water flows through pipes either by gravity, either by assistance of a pump. In the first phase of an emergency, the pipes, such as spiralled (Heliflex) pipes or flat hose, may be laid on the surface, but this results in the water getting hot, which renders the water less palatable and potentially reduces the remnant effect of the Free Residual Chlorine. In a later stage, the pipes will have to be buried at a depth of at least 0.5 m (deeper in cold climates), laying on a sand bed of a few centimetres thick. Although spiralled pipes could still be used for buried systems, it's preferable to install PVC or polyethylene (PE) pipes. Well designed and installed systems (T.B. 2.30; 2.31; 2.32 and 2.33) can last for several years.

Storage

Correct storage ensures that a sufficient quantity of drinking water is available when the consumers need it. Storage is required for:

- balancing the water demand and water production (certainly at peak moments);
- providing a back up when there is a break-down or when maintenance is required in the system;
- ensuring a constant supply to or from a treatment process.

All kinds of pre-fabricated (emergency) reservoirs are available with their specific volume, use, advantages and inconveniences (T.B. 2.35; 2.36; 2.37). In case a reservoir would be constructed on the spot (e.g. T.B. 2.38), use plans that are approved by your technical referent in order to avoid accidents.

Water delivery point

The water delivery point is crucial in the water chain as it might be a point where a lot of water is lost and (re-)contamination occurs. Water may be delivered through individual connections or at public water points.

- Individual connection: Ideally, water should be provided inside or near each house. It will usually lead to a significant increase in water consumption, even if only a single tap is installed. Individual connections should be considered when managing long-term water supply in a grouped habitat area, and certainly for health structures in chronic emergencies and stabilized situations. However, keep in mind that for each water delivery point, an evacuation of the spilled water needs to be foreseen as well.
- Public water point: In many cases, it won't be possible to construct individual connections. It is known however that once the distance from the water point to the dwelling exceeds 100 m, the quantities collected decrease drastically, to reach a point where only the survival minimum is taken. The waiting time at the delivery point is also of importance; the longer it is, the lower the potential amount of water that will be collected. It is recommended to allow at least one tap per 200 - 250 persons, certainly in closed settings such as camps. Sufficient taps should deliver enough water to the consumers within a reasonable time, in order to avoid pushing and shoving at the distribution point. This implies as well that the delivered flow should be high enough (minimum 10 l per minute a tap), especially during peak hours. In case wells are provided with a hand pump, there should be one pump per 500 persons (maximum 750 persons during acute emergencies). Queuing at water points should be organised and controlled by community members, certainly during acute emergencies. Special attention should be given to the access to water for vulnerable groups (children, physically impaired people and the elderly).

Collection and household storage

To be able to collect the water that is provided to them, and to store and use it correctly at household level, the beneficiaries should have enough appropriate recipients with a sufficient capacity. If this isn't the case, it is a top priority to distribute containers.

A water storage capacity of 40 l per household should be considered as a strict minimum, with suitable recipients having a volume of 10 to 20 l. In order to avoid internal contamination, the containers should ideally have a small opening for the water to be poured out instead of dipping into them. The cap should always be replaced on its opening when the container isn't in use to prevent contamination by dirty hands, dust and animals. Closable empty plastic cooking oil jerrycans and traditional clay containers may be suitable as long as they are covered. Regular cleaning and potential disinfection of household storage recipients is necessary.

In case taps with a continuous water supply are available within the health structure / dwelling, the technical step of "household storage" seems less important. However, it is always wise to have a back up storage with some recipients when the water supply system needs maintenance, or in case it would fail.

2.5 Further reading

Action Contre la Faim

Water, sanitation and hygiene for Populations at Risk
Hermann, 2005

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Engineering in Emergencies: a Practical Guide for Relief Workers
Intermediate Technology, RedR, 2002

S. House, B. Reed

Emergency Water Sources
Water, Engineering and Development Centre (WEDC), 1997

T.D. Jordan

A Hand Book of Gravity-Flow Water Systems
Intermediate Technology, 1980

S.B. Watt

Ferrocement Water Tanks and their construction
Intermediate Technology, 1993

S.B. Watt, W.E. Wood

Hand Dug Wells and their Construction
ITDG, 2003

T.B. 2.01 Water intakes

Intakes are facilities to collect water from its source, which goes either to treatment and/or storage, or in some cases directly to the users. Water moves through the intake either by gravity, or it has to be lifted. It is an important stage because it has to be well designed to avoid loss and (further) contamination of the water.

Surface water

Rivers and streams usually have a wide seasonal variation, and this will affect the location of the intake. During the raining season, floods can occur that may destroy the intake, and during the dry season, the flow may disappear completely. In a fast flowing river, erosion may be a problem. The intake should be located away (preferably upstream) from contamination sites such as bathing and washing zones, animal watering places and latrines.

A direct intake with motorised (surface) pumps is the most common method used during emergencies (T.B. 2.28). The intake should be placed at least 0.3 m below the water surface, to minimize floating debris, algae or aquatic plants to be pumped up. Water containing a lot of plant life and organic matter may have unacceptable taste and odour, and will drastically increase the chlorine demand for disinfection. The pump's intake should not be placed too close to the bottom either (preferably a minimum distance of 0.5 m, and certainly not less than 0.3 m). It may disturb the sludge and/or the settled particles, which render the pumped water very turbid. In practice, the intake equipped with a strainer should be kept in place by means of a floater and some kind of an anchor or a rope. In case a (small) river would be less than 0.6 - 0.8 m deep, its depth can be increased by constructing some kind of dam, called a weir. In acute emergencies, simple materials such as sand bags (possibly mixed with some cement) can be used for the construction of a weir.

A division on a river can sometimes be sufficient as an intake. But open channels don't provide any protection against (further) contamination of the surface water. Piped systems provide better protection if they are fitted with a screen and possibly with a structure that helps retaining the water (e.g. a dam), in order that the inlet always stays under the water level.

In chronic emergencies and stabilised situations, time is a less critical factor. Thus it is recommended to invest in more sustainable solutions such as infiltration wells and galleries if surface water has to be taken from rivers. These alternatives provide several advantages:

- One can be sure that there is water available because they are located nearby (visible) water sources.
- A certain quantity of water is most of the time accessible, even in seasons when the river itself would dry up.
- They improve the water quality by filtering out debris and sediments, and in some cases also quite some pathogens (chlorination stays recommended however).

In fine or compacted soil, the infiltration wells should be placed at least 2 m from the river. In coarser soil, the distance might have to be increased to 15 m. To increase the yield of the infiltration well, infiltration galleries can be added. These infiltration galleries are pierced water collecting ducts that are specifically designed for that purpose or locally made out of PE or PVC pipes with a diameter of at least 100 mm. They are buried in the river bed itself, or in a trench dug parallel to the river. The trench will have to be about 1 m below the water level in the dry season, and filled with a filtering layer of gravel and/or coarse sand around the pipe. Another possibility is to drive pierced galvanised iron pipes perpendicular to the river. This method is much more difficult to install, as solid pipes are not easily available and driving them may be problematic.

Obviously, the water will have to be lifted out of the infiltration well. This can be done with the same means as for normal wells (as described below).

Groundwater

Groundwater often has a better physical and microbiological quality than surface water. It is therefore very important that the quality of the groundwater stays guaranteed by means of correct intakes. Amongst the different groundwater sources, only springs can have a direct gravity flow system by means of one or several spring catchments (T.B. 2.08).

To collect real groundwater (at least 3 m deep), hand dug wells can be constructed (T.B. 2.02; section 2.5 Further reading). Tube wells (boreholes) can be an interesting alternative because they can be made rapidly, at least if the required drilling equipment is available. Several methods, as well manual as motorised techniques exist to construct tube wells. With the exception of jetting (T.B. 2.07), constructing tube wells with motorised techniques is a specialised work that should be left to professionals. Advice should always be looked for from your technical referent before contracts are signed with local companies.

Wells will require a mechanism to lift the groundwater to the surface, such as a pulley, a windlass or a shaduf. Alternatives to lift the water are hand or motorized pumps, being indispensable for small diameter boreholes. The common aim of all these lifting mechanisms is to ease the task, while avoiding that the water source gets contaminated.

Hand pumps can be divided in suction pumps and deep-well pumps. Suction pumps have their piston above the water level, which makes them simple in design and maintenance, but have the inconvenience that they certainly can't be used if the water table is more than 7 m deep. When they haven't been used for some hours, it might be necessary to re-prime them to be functional. Unfortunately, the re-priming is often done with water that has been polluted (e.g. by a dirty recipient) and therefore contaminates the whole well.

Deep-well hand pumps are preferred over suction pumps under all circumstances, and are the only possibility anyway if the water table is more than 7 m deep. Different kinds of deep-well pumps exist with all their own specifications. The choice on the most appropriate deep-well hand pump depends on physical factors such as the depth of the water level and the yield of the well, but also on the pump's characteristics (yield), its price, its lifespan, and most importantly its existing presence in the region. The latter is an indicator if spare parts might be available within the region, and if some people know how to maintain and repair the pumps. In case several models would respond to the above specifications, choose the VL0M type (Village Level Operation and Maintenance), if available.

The choice of a motorized pump type (T.B. 2.26) will depend on the required flow, but also on the kind of groundwater intake (hand dug or tube well) and the water table depth. Certain motorized surface pumps (T.B. 2.25) can be used to lift water from shallow wells (less than 7 m deep). For deeper hand dug wells, professional de-watering pumps (T.B. 2.25) can be used. Deep tube wells will demand mostly a real submersible pump (T.B. 2.25), if motorisation is required.

Rainwater

Rainwater, collected far away from industrialized and urban areas, represents normally good quality characteristics, if it's harvested correctly. It may represent an important source of water, although its variability along the seasons is generally important. Rainwater can be collected from any clean surface, roof catchments being one of the most used. The water is then transferred to tanks via gutters and pipes. The contamination of harvested rainwater comes primarily from the first rains, rinsing away the accumulated dirt on the roof. Correct catchment techniques will discard the contaminated rinsing water before the rainwater is stored in completely closed reservoirs (T.B. 2.09).

Remarks

- There are many factors that will influence the choice of the water intake. It will depend mainly on the source, the topography, the context (acute or chronic emergency, stabilised situation), the quality of the water (e.g. turbidity) and the preference of the beneficiaries.
- Where simple intake facilities might be sufficient in the beginning of an emergency, they most probably will have to be improved over time, as the intake itself can have a serious influence on the quality of the water. Source protection should be preferred over water treatment, certainly in stabilised situations.

T.B. 2.02 Description of a hand dug well

A well is a hole that pierces an aquifer so that the groundwater can be lifted out, potentially by a pump. Usually, the hole that pierces the aquifer is named a hand dug well if it has been excavated manually. Hand dug wells can provide important quantities of water, if their location is properly assessed and chosen, and if they are constructed correctly. This technical brief provides a description of the most common parts of a hand dug well and their purpose. It doesn't explain the construction of a well itself, because there are numerous techniques that are well described in many existing technical books. The selection of a construction technique will depend on the soil conditions, the local knowledge and expertise, and the availability of material and equipment.

Principle parts of a well

Properly constructed wells give not only access to the groundwater, but they also prevent its contamination. Therefore should a correct well consist of an underground and an aboveground part.

Underground part

Intake: As it is the part that pierces the aquifer, the intake is the most important component of the well. To allow groundwater to get inside the well, the intake lining should be made of permeable or perforated (concrete) rings (T.B. 2.06) bolted and/or mortared together, or of open-jointed (honeycombed) masonry walls. The lining allows the groundwater to trickle through, while it avoids the well to collapse and soil (e.g. sand and/or gravel) to enter. It is important that the intake has enough wall surface for sufficient quantities of groundwater to enter the well. For a well with an intake diameter of around 1 m, it is recommended that it pierces the aquifer by about 2 m during the dry season, or even more in case of a low soil permeability. In addition, the quality of the intake lining has a direct influence on the well's yield, and sometimes also on the quality of the collected groundwater. Permeable concrete rings will retain fine aquifer particles from intruding into the well. These fine particles may also damage pumping systems.

Graded aggregate filter: Water should enter mainly by the vertical walls of the intake and not too much via the bottom of the well. The graded aggregate filter, positioned on the bottom of the well, catches particles settling down which may otherwise get / stay in suspension while the groundwater is withdrawn. This graded aggregate filter is especially useful in fine sand aquifers as it won't be swirled up from the bottom when water is retrieved from the well.

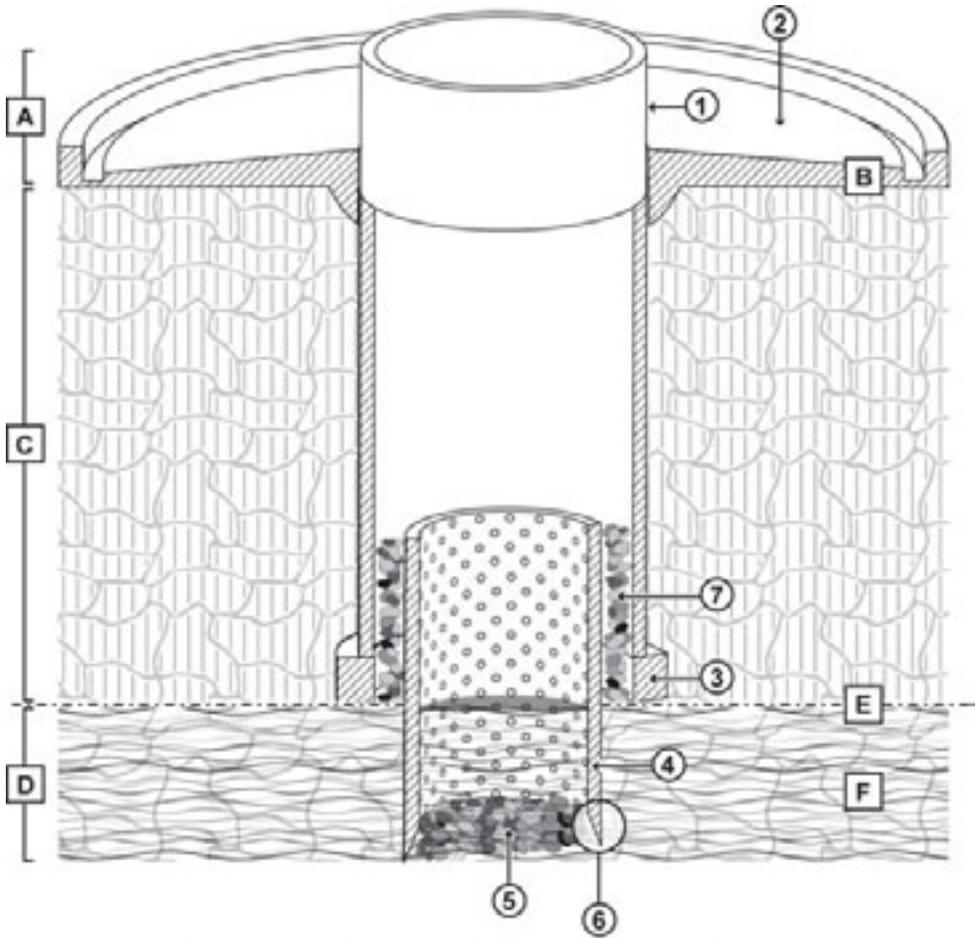
Shaft: The underground part of the well above the water table is called the shaft. To avoid that the well collapses and that there would be a direct ingress of polluted water from the surface, the shaft should be reinforced with impermeable (concrete) rings or sealed masonry walls (called lining). If made of (concrete) rings, they should be bolted and/or mortared together.

Aboveground part

Wellhead: The extension of the shaft lining raised aboveground is called the wellhead. It should be about 0.3 m above the apron for closed wells with a hand pump and at least 0.8 m for (open) wells without a hand pump (still preferably with a safe lifting mechanism and closable). Made out of impermeable concrete rings or sealed masonry walls, the wellhead should protect the well water from surface pollution. It is also a safety measure to avoid users falling into an open well.

A lid on the wellhead protects the well from becoming contaminated by (dust) particles and bird droppings, and it can provide a support for the lifting mechanism. The lid can be completely removable, but for closed wells equipped with a (hand) pump, it is advised to foresee a manhole, permitting future maintenance and repairs.

Apron: A concrete slab around the wellhead, called the apron, together with an anchorage should be made as an extra protection to avoid contaminated water (e.g. water used to rinse the users' recipients) polluting the well water. The slope of the apron (at least 1%, preferably 2%), together with the protective kerb lead the wastewater away from the well, via a drainage channel (2% slope) towards an infiltration system (T.B. 4.06; 4.07; 4.08), a garden or a drinking trough for animals. Certainly in cold countries, it is advised to have some kind of foundation underneath the edge of the apron. This should avoid water getting underneath the apron, which could crack if the water starts to freeze.



Key

Hand dug well with telescoping principle

- | | |
|---|---|
| A. Wellhead (with lid / lifting mechanism) | 1. Impermeable concrete rings or sealed masonry lining |
| B. Apron with protective kerb and anchorage | 2. Reinforced concrete slab with anchorage |
| C. Shaft | 3. Foundation anchorage |
| D. Intake with graded aggregate filter | 4. Perforated / permeable concrete rings (or open-jointed masonry lining) |
| E. Water table (static water level) | 5. Graded aggregate filter (cleaned gravel) |
| F. Aquifer | 6. Cutting ring |
| | 7. Backfilling (cleaned gravel) |

Remarks

- For the well water to be of drinking quality, it should have gone through the natural soil filtration process and be considered as “groundwater” as opposed to “surface water”. As an approximate value, if the water level is at 3 m or deeper, it can be assumed that it is groundwater.
- Correct siting of a new well requires (local) expertise because there are several parameters to take into consideration (e.g. presence of vegetation, other water sources, geological parameters, safe distances from pollution points). A geologist, geophysical equipment and hydrological maps can be helpful to find the right spot to construct a well (for more information, contact your technical referent).
- Under normal conditions, the time required for the complete construction of a proper hand dug well could be a matter of several weeks. However, it may take much longer if the aquifer is situated very deep and/or in adverse soil conditions, such as hard rock.
- Hand dug wells should normally be constructed during the dry season when the water table is at its lowest level. If constructed during the rainy season (when the water table is mostly higher), there is a considerable risk that the well will run dry during the dry season and that it will have to be deepened using the telescoping method.
- The intake can be constructed with its outer diameter smaller than the shaft’s inner diameter, which is called telescoping. This technique permits deepening the well when it would run dry, because additional intake rings can be installed which will “slide” downwards in the shaft when further excavation takes place. If this kind of well would be constructed during the rainy season, it is recommended to foresee some additional porous or perforated intake rings in case the well would dry up in the dry season.
- It is important to install a correct water lifting mechanism on a hand dug well. A recipient (e.g. bucket) with rope is a simple and cheap lifting mechanism, but has several inconveniences:
 - The person lifting the water stands at the edge of the open well and risks to fall in.
 - When the recipient and rope are not in use, they will often be lying on the ground, thus picking up dirt and pathogens that will be introduced in the well and contaminate it.
- A windlass will avoid that the rope comes in contact with the ground and therefore reduces the risk of well contamination. It also permits to hoist bigger and heavier recipients in a safe manner.
- A shaduf is a lever permitting to lift water out of (very) shallow wells. The counterweight on the shaduf will make it easier to lift a heavy recipient out of the well. The counterweight will also avoid that the recipient touches the ground when it is not in use, which helps to keep it away from contamination.
- Installing a hand pump makes water collection easier for the users, but it also prevents potentially contaminated objects like buckets from being introduced into the well. On top of that, the well can be completely closed (with access via a manhole), avoiding dust and bird droppings falling in. Suction hand pumps can still be found on the field. They have their piston above the water level, which makes them simple in design and maintenance, but have the inconvenience that they certainly won’t work if the water table level is more than 7 m deep. When they haven’t been used for some hours, it might also be necessary to re-prime them in order to be functional. Unfortunately, the re-priming is often done with water that has been polluted (e.g. by a dirty recipient) and therefore contaminates the whole well.
- Deep-well hand pumps are preferred over suction pumps under all circumstances, and are the only possibility anyway if the water table is more than 7 m deep. Different kinds of deep-well pumps exist with all their own specifications. The choice on the most appropriate deep-well hand pump depends on physical factors such as the depth of the water level and the yield of the well, but also on the pump’s characteristics (yield), its price, its lifespan, and most importantly its existing presence in the region. The latter is an indicator if spare parts might be available within the region, and if some people know how to maintain and repair the pumps. In case several models would respond to the above specifications, choose the VLOM type (Village Level Operation and Maintenance), if available.
- Motorized pumps offer the same advantages as hand pumps but have most often a higher capacity, which is interesting to cover bigger water demands. However, the pump capacity should not be too high and certainly not surpass the maximum pumping rate of the well (T.B. 2.27). Over-pumping will (drastically) increase the turbidity of the well water, and might even cause the surrounding soil to sink. The latter can cause serious damage to the well and certainly to the apron that starts to crack as there isn’t any supporting ground underneath anymore.
- Backfilling around a well can be done, but only with concrete or non-contaminated earth (e.g. the use of earth collected at termite hills is prohibited as it contains a lot of nitrates / nitrites, which is potentially harmful).

T.B. 2.03 Cleaning and disinfection of a well

The cleaning and disinfection procedure is done with the objective to eliminate pathogens (bacteria and viruses) that could be present in the well. This procedure is implemented after the well is built or after maintenance or rehabilitation works have been done inside the well or on the pump. It can also be done when there are some reasons to suspect that a contamination was (punctually) introduced in the well (e.g. floods), or if a sanitary inspection shows a risk of an existing pollution.

Operation

Technique A.

If it is possible to empty the well completely, it's the preferred method as it gives the best results.

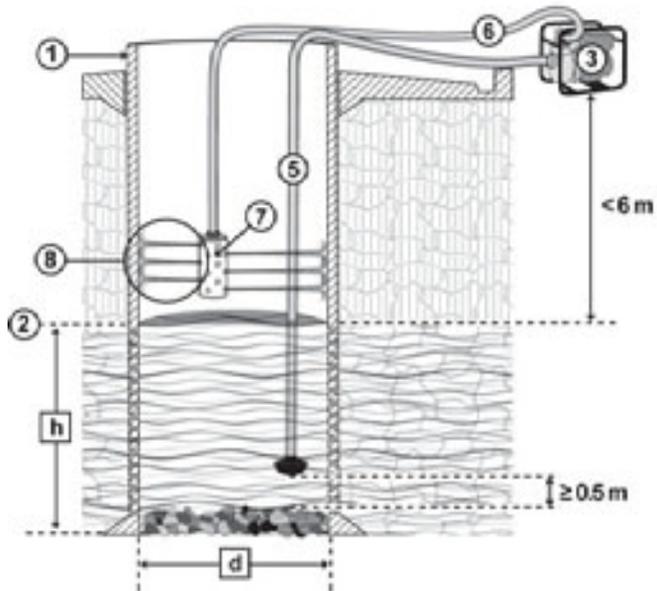
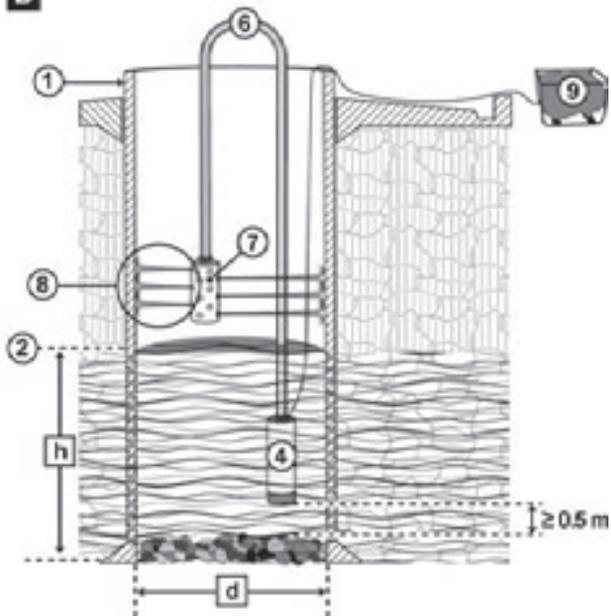
- Empty the well by means of a pump. Be aware that the well depth can't exceed 7 m (at sea level) if a surface pump (e.g. motor pump) is used. If the water table is deeper, a dewatering pump will be needed (T.B. 2.25). The sludge can potentially be removed by putting the "suction" pipe / dewatering pump very close to the bottom of the well and swirl the groundwater to put the mud in suspension.
- Remove all the potential debris that has entered the well (after an accidental event like a flood), using a strong metal bucket lifted by means of a winch and tripod. Make sure to follow all the safety prescriptions (see hereunder). Deepen the well in case of a massive influx of sludge.
- Prepare a 0.05% chlorine solution (T.B. 2.20). The amount of chlorine solution needed will depend on the total surface of the wellhead, shaft and intake.
- Scrub the complete lining with the chlorine solution, following the safety prescriptions (see hereunder).
- Wait at least ½ hour during which the well refills.
- Pump the water carefully out of the well again, while measuring the turbidity (T.B. 2.13) and the Free Residual Chlorine (FRC) concentration (T.B. 2.22). The pump can be stopped when the turbidity is lower than 5 NTU and the FRC concentration lower than 0.5 mg/l.

Technique B.

If it is not possible to empty the well completely, this method is the most effective.

- Try to remove as much sludge and debris as possible (after an accidental event like a flood) by means of a surface pump (if the water table < 7 m deep) or a dewatering pump (water table even > 7 m deep).
- Prepare a 0.05% chlorine solution (T.B. 2.20). The amount of chlorine solution needed will depend on the surface of the lining above the water table, including the wellhead.
- Scrub the lining above the water level with the 0.05% chlorine solution according to the safety prescriptions (see hereunder).
- Determine the volume of water inside the well: **volume = (π x d²/4) x h**
with π = 3.14; d = inner diameter of the well; h = depth between the water table and the well bottom
- Prepare a 1% chlorine mother solution (T.B. 2.20). The amount of chlorine solution needed will depend on the water volume in the well.
- Add 10 l of the 1% solution per m³ of well water, mix and leave the well closed for at least 12 hours.
- Pump the water carefully out of the well after this period, while measuring the turbidity (T.B. 2.13) and the FRC concentration (T.B. 2.22). The pump can be stopped when the turbidity is lower than 5 NTU and the FRC concentration lower than 0.5 mg/l.

Key	Input
A. Well cleaning of shallow well with motor pump (technique C)	
B. Well cleaning of well with dewatering pump (technique C)	
1. Lining	-Chlorination kit with a chlorine-generating product
2. Water level	-Scrubbing brushes (short and long handled)
3. Surface (motor) pump	-Extension for the handle of the scrubbing brush
4. Dewatering pump	-Hoses and disinfection tube (pierced sleeve)
5. Suction pipe	-Ropes, buckets
6. Delivery pipe	-Pump kit (motor or dewatering pump)
7. Sleeve with small diameter holes	-Tripod and winch
8. Water jets	-Harness / seat
9. Generator	-Mask
	-Goggles or face shield
	-Heavy duty gloves
d = diameter of the well	-Overall
h = depth between water table and bottom	-Temporary fencing material

A**B**

Technique C.

If a lot of wells need to be cleaned and disinfected in a short period (e.g. after a big flood), this method is preferred because it's the fastest, but it's also the least effective.

- Try to remove as much sludge and debris as possible by means of a surface pump (only if the water table < 7 m deep) or a dewatering pump (even for a water table > 7 m deep).
- Determine the volume of water inside the well: **volume = $(\pi \times d^2/4) \times h$**
with $\pi = 3.14$; d = diameter of the well; h = depth between the water table and the well bottom
- Prepare a 1% chlorine mother solution (T.B. 2.20). The amount of chlorine solution needed will depend on the water volume in the well.
- Add 100 l of 1% chlorine solution per m³ of well water, mix and leave the well closed for 30 minutes.
- Equip the delivery hose of the pump with a disinfection tube, which is a pierced sleeve (small holes of 4 - 6 mm diameter), closed at one extremity. The highly chlorinated well water being pumped through the small holes of the disinfection tube will result in strong jets, permitting the cleaning and disinfection of the well lining above the water table.
- Start the pump and move the disinfection tube up and down for at least 15 minutes, in order to spray thoroughly the shaft and the wellhead (T.B. 2.02) with a high flow of the highly chlorinated well water. When the well is completely cleaned, wait 30 minutes for the chlorine to act.
- Pump the water carefully out of the well after this period, while measuring the turbidity (T.B. 2.13) and the FRC concentration (T.B. 2.22). The pump can be stopped when the turbidity is lower than 5 NTU and the FRC concentration lower than 0.5 mg/l.

Safety prescriptions

Safety measures must seriously be considered before starting the cleaning of a well. This includes the safety of the workers and the equipment, but also the surroundings of the working area:

- The working area should be fenced all the time, with no access to people other than the authorised personnel.
- Supervised by a competent and trained team leader, there must be a minimum of three trained workers per well. Two workers should be at the surface, one operating the winch and the other watching the third person inside the well. All three workers should rotate, every 15 minutes ideally. A clear and simple system of communication must be used between the person inside the well and the workers remaining at the surface.
- All workers should wear a helmet, an overall, heavy duty gloves and boots. When manipulating chlorine products, goggles or a face shield, a respirator and rubber gloves should be added.
- The staff should be trained to use the material correctly, including the safety equipment present on site like the lifting apparatus with harness and the first aid kit.
- Chlorine is a dangerous product that must be stored and handled with great care (T.B. 2.19). The manual disinfection (scrubbing) of the lining should be done as much as possible with the staff being outside of the well, by means of long handled hard brushes.
- All tools and safety equipment should be checked daily and replaced when necessary.
- Electric dewatering pumps can be used to empty a well before cleaning. However, a dewatering pump should be stopped and disconnected from its electricity source before people enter the well, as faulty equipment could cause electrocution.
- A generator used to provide power to electric pumps, should always be earthed.
- Generators and motor pumps should be located as far as possible away from the well to avoid exhaust gases entering, potentially causing asphyxia of people working inside. For the same reason should motor pumps never be lowered inside a well.

Remarks

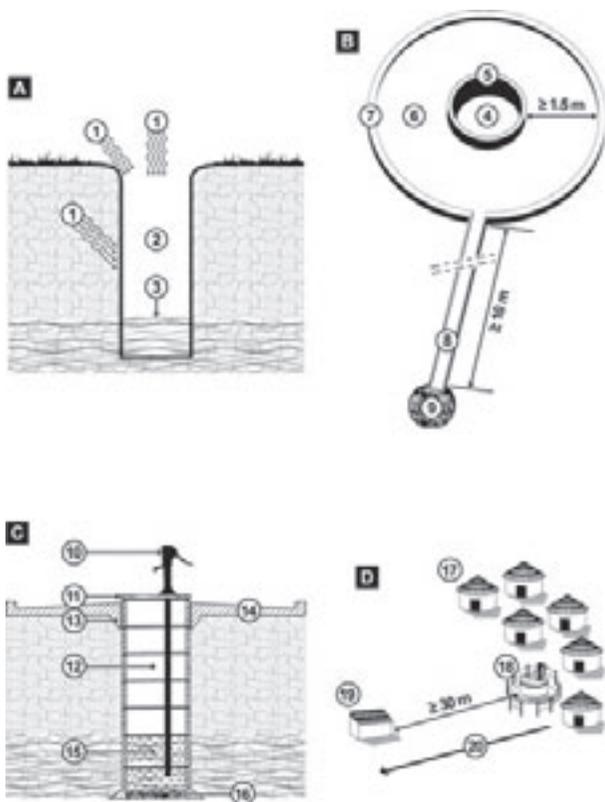
- The cleaning techniques described above are meant for lined wells. The cleaning and disinfection of an unlined well is not very useful, except perhaps after being flooded. Unlined wells should not be entered, especially not after they have been flooded because they might collapse. In such a case, it can be tried to remove the sludge by pumping, although it will be impossible to take out the potential big debris. The dirt layer on the unlined walls can be removed by technique C, but care should be taken not to erode the walls (any further), as this could lead to (partial) collapse.
- In general, a properly protected well (T.B. 2.04) is considered as being non-polluted. Nevertheless, a biyearly maintenance before and after the rainy season, including cleaning and disinfection is strongly recommended.
- The described types of cleaning / disinfection do not have any permanent effect. These kinds of interventions are effective on punctual contamination linked to maintenance or construction works, or accidental pollution (e.g. floods), but not for unprotected wells. If the source of contamination is not removed, water taken out of the well will not be disinfected due to the very temporary impact of chlorine.
- In any case, possible contamination sources must be searched and corrective measures applied before the disinfection of the well can occur.
- Microbiological contamination of a well through the ground by latrines or cattle is quite rare, unless the contamination source is located at a short distance from the well (the minimum recommended distance for latrines is set at 30 m, and 10 m for cattle). If the contamination really occurs through the ground, it could be necessary to close the well or to eliminate the source of contamination (e.g. latrines), knowing that it will take a minimum of 60 days before the adverse microbiological effects have disappeared. If the well is the only water source, implementation of bucket chlorination (T.B. 2.23) can be considered to reduce the risks and to give time to seek and implement an alternative solution.
- Potential damages to the outside (T.B. 2.04) and the inside lining of the well, discovered during or after the cleaning, should always be repaired. The repaired patches should be disinfected before the well is put back into function.
- When a well has to be emptied, the first (non-disinfected) water pumped out of the well should preferably be disposed of via a soak away pit (T.B. 4.06) or infiltration trenches (T.B. 4.07).
- In case a well has to be emptied during of a cholera outbreak, it is strongly recommended to hyperchlorinate the well water before, because of the environmental contamination risk by the potentially polluted groundwater. Per m³ of well water, 100 l of 1% chlorine solution should be added.
- Since this chlorination method does not guarantee a continuous disinfection, it is strongly recommended to implement controlled bucket chlorination (T.B. 2.23) as long as the well is not properly protected or if there is a strong suspicion that the well is the origin of infection of several people.
- Debris and sand inside a tube well (borehole) can't be removed manually, but can be blown out by means of a compressor. Other techniques exist but fall out of the scope of these guidelines. Contact your technical referent for more information when required.
- The disinfection of a tube well (borehole) can be done by pouring 10 l of 1% chlorine solution per m³ of water within the well (as described for technique B). For the whole casing to be disinfected, it is advised to pour the chlorine mother solution over the whole circumference of the tube well. Pump the water carefully out of the tube well after a minimum period of 12 h while measuring the FRC concentration (T.B. 2.22). The pump can be stopped when this concentration is lower than 0.5 mg/l. Do not forget to pour an abundant amount of potable water afterwards in the tube well to rinse stagnant chlorine solution on the couplings of the raising main.

T.B. 2.04 Protecting a shallow well

A well should normally be protected as soon as it is dug. But existing wells are often found without protection or even without lining. Protection consists of preventing contaminants getting into the well, and preventing the infiltration of runoff and wastewater which could carry contaminated material. Lastly, protection strengthens the structure of the well, resulting in a longer lifespan.

Operation

- Prepare the site: remove all debris, install a fence and bring in the needed material and equipment.
- Line the existing well completely. Ideally, some kind of foundation (e.g. concrete 300 kg/m³; T.B.2.05) should be made first at the bottom, but emptying the unlined well completely could lead to its collapse. This means that the concrete foundation should be poured under water or be prefabricated and then lowered inside the well. Concrete rings that are bought or fabricated locally (T.B. 2.06) should be placed on top of the foundation. The rings underneath the water table should be perforated. All rings should be bolted and/or mortared together. The uppermost ring should extend well above ground level.
- Place a layer of gravel, the graded aggregate filter, on the bottom of the well. This layer of about 0.1 m thick will avoid the re-suspension of settled particles.
- Fill the gap between the (perforated) rings and the sides of the well with gravel. The height of this gravel pack should reach (just) above the water table level.
- Compact a thick clay layer above the gravel. In case of limited availability of clay or a difficult access within the gap, pour cement grouting (viscous liquid mortar) on top of the clay (a thin layer at least).
- Backfill the pit with compacted soil. If cement grouting has been used, the backfilling should only be done once it has hardened enough (at least 3 days).
- Excavate around the wellhead to a radius of at least 1.5 m, until all vegetal (black) earth is removed. This excavated area will be the basis of the apron. At the circumference of the future apron, a deeper trench can be made for a foundation. This foundation is mandatory for cold countries to avoid that water can get underneath the apron, which could crack if the water freezes.
- Continue to dig a triangular trench around the wellhead (as per figure C) with a depth of at least 0.3m, in order to prepare the construction of the obligatory anchorage.
- Dispose of all the removed material.
- Bend reinforcing bars into triangles for the anchorage.
- Prepare a horizontal grid of reinforcing bars for the apron, with meshes of 0.2 m x 0.2 m. The size of the grid depends on the excavated area.
- Interconnect the triangles in a circular pattern to the horizontal grid with metal wires. The diameter of the circular pattern should be slightly bigger than the outer diameter of the wellhead.
- Fit the assembly inside the excavated area around the wellhead. The reinforcing bars should be minimum 30 mm away from the concrete ring and the bottom of the excavation.
- Cast the anchorage and apron in homogeneous concrete layers (300 kg/m³) and vibrate the concrete. Once the concrete starts to settle, the apron's cone should be created, sloping itself towards the foreseen drainage channel. Both the tilt of the cone, as the cone itself should have a slope of minimum 1%, preferably 2%.
- Build on the apron's circumference a protective kerb with a minimum height of 0.1 m. The protective kerb helps to direct the spilled water via a cemented / concrete drainage channel (slope 2%) towards a soak away pit (T.B. 4.06), infiltration trenches (T.B. 4.07) or potentially an evapo-transpiration area (T.B. 4.08), which should be at least 10 m away from the well. When the well area isn't used for activities needing soap such as laundry and personal hygiene, a grease trap isn't necessary, and interesting alternatives for the evacuation of spilled water can be an irrigated garden or a cattle drinking trough.
- Extend the height of the wellhead if needed. This can be done with a concrete ring or masonry-work. A closed wellhead provided with a hand pump should rise about 0.3 m above the apron, whilst one without at least 0.8 m.
- Provide a (concrete) cover (either removable or fitted with an inspection hole), on which to mount a lifting mechanism.
- Install preferably a complete pumping system, according to the pump manufacturer's instructions. A pump makes the retrieval of the water easier for the users, and is also useful because it prevents contact between contaminated objects like buckets and the well water.



Key

Input

- A. Unprotected well
 B. Protected well with an apron and a drainage channel
 C. Completely protected well with a hand pump
 D. Minimal safety distance

1. Possible entrees of pollution
2. Well
3. Water surface
4. Well entrance
5. Wellhead
6. Concrete apron
7. Protective kerb
8. Drainage channel (to infiltration system)
9. Infiltration system / garden
10. Pump
11. Cover slab
12. Impermeable concrete rings
13. Anchorage
14. Apron with protective kerb
15. Perforated concrete rings
16. Graded aggregate filter (about 0.1 m)
17. Houses / dwellings
18. Well
19. Latrines
20. Run-off direction

- Cement, sand and gravel (300 kg/m³ concrete)
- Reinforcing bars (minimum 6 mm), metal wires
- Clean, non salty water (to prepare concrete)
- Tools to make and cast concrete
- Bricks (to make protective kerb)
- Concrete rings; diameter depending on:
 - the dimensions of the existing well
 - the availability on the local market (local purchase)
 - the size of the mould (local fabrication)
- Perforated concrete rings
 - if not available on the market, drill holes in plain rings
 - local fabrication
- Cover that fits on the wellhead
- Tripod and lifting equipment
- Safety gear
- Hand pump with fixtures and fittings
- Construction materials for the drainage system
- Fencing material
- Experienced mason

Remarks

- The technique described above is to protect an existing shallow well.
- Respect the minimum safety distances: no latrines closer than 30m from a well, no cemeteries or (medical) waste zones that include organic waste pits closer than 50 m. Latrines, cemeteries and (medical) waste zones should be downhill from the well.
- A fence around the well is strongly recommended:
 - before the works start, in order to avoid non-authorized people entering the site. This will reduce the risk of accidents.
 - after the works have finished to protect the improved well even more, certainly if there are animals (e.g. cattle) around.
- Lowering rings in the well should be done with a tripod, security equipment and by an experienced team.
- A skilled mason is required to make the apron with the correct cone and tilted slopes. A square apron is slightly easier to construct as it only needs to be tilted (no cone), but special attention should go to the slope at the corners. When the slopes aren't correct, spilled water will be stagnating, which could become a breeding ground for several vectors.
- Before the first use, after maintenance or after accidental pollution, disinfect the well with a chlorine solution (T.B. 2.03).
- It is strongly recommended to avoid (domestic) activities like dish washing, laundry or personal hygiene directly around the well site, as this could potentially lead to the contamination of the well water. Separate services like showers (T.B. 4.01) or a washing area (T.B. 4.02) should be installed with their own waste water facilities; a grease trap (T.B. 4.04) and an infiltration system.
- The apron should be cleaned regularly, together with the drainage system. Possible cracks of the apron should be repaired. Regular check-ups, preventative maintenance and potential repair of the pump system should be done.

T.B. 2.05 Mortar and concrete preparation

Mortar and concrete are frequently used in construction. In complying with some preparation and implementation recommendations, these materials will have a lifespan exceeding 20 years, while keeping up their properties. They ensure a good bonding between the materials, a distribution of the loads whilst being resistant to them, and a low deformation. Mortar is a mix of cement, sand and water. Concrete has the same ingredients and includes additional gravel.

Composition

Sand

It must be clean and washed, without silt or impurities (soluble, soft or carbon materials). Sand used for masonry-work can contain a little bit of clay, but none at all for cement plaster (river sand is therefore recommended). Avoid sea sand because salt impairs with the bonding of the cement.

Gravel

Originates naturally from river beds or from crushing rocks. It cannot contain earth or plants.

The selected grain size of the above products varies according to the use:

Grain size (mm)	Quality	Use
0.1 - 0.5	Fine sand	Smooth cement plaster
0.5 - 2	Medium sand	Cement plaster, mortar for masonry
2 - 5	Grainy sand	Mortar for masonry
5 - 20	Gravel	(Reinforced) concrete

Cement

It is a mixture of clay (5 to 25%) and limestone (75 to 95%), fired at 1400°C. Afterwards the mixture is finely pulverized.

Mixing water

It must be clean, without impurities. Avoid sea water and water containing organic or chemical matters.

The addition of water to cement creates a chemical reaction (hydration) and produces hydrates with a crystal formation. When water is added, a malleable mixture should be obtained and the appearance of crystals causes the setting phenomenon (from 1 to 4h), followed by the hardening. During the hardening process, the mortar / concrete will acquire its resistance. The time rate at which concrete hardens depends a lot on the ambient temperature.

Proportions and uses

The respective proportions of the different constituents depend on the planned use of the mortar or concrete, as presented below. The quantity of cement is often mentioned to define the proportioning. Practically speaking, proportions are usually indicated in kg for the cement (generally provided per 50 kg bags) and in litre for sand and gravel. Masons often work with proportions of a number of wheelbarrows of sand (and gravel) per bag of cement (50 kg).

	Cement	Sand	Used for:
Mortar	20 kg	60 l	<ul style="list-style-type: none">• making cement blocks• masonry-work, joining:<ul style="list-style-type: none">- fired bricks- cement blocks
	2/5 of a 50 kg bag	1 wheelbarrow	
Cement plaster	25 to 30 kg	60 l	<ul style="list-style-type: none">• smoothing surfaces• watertight masonry surfaces• watertight unions between pipes and masonry-work
	half a 50 kg bag or more	1 wheelbarrow	

(1 wheelbarrow = 60 l).

The total quantity of water to be included in mortar or concrete depends of the natural humidity level of the sand. For 150 kg/m³ concrete, about 90 l of water will be needed for 1 m³ of concrete. For 300 kg/m³ concrete, the amount of water required will be about double.

Amount of the different constituents needed to make 1 m³ of concrete with crushed rock or river gravel:

	Cement	Sand	Gravel	Used for:
Lean concrete 150 kg/m³	150 kg	400 l	800 l	<ul style="list-style-type: none"> • base of lined pits • floor slabs like: <ul style="list-style-type: none"> - washing areas - showers - tapstands
	3 x 50 kg bags	7 wheelbarrows	14 wheelbarrows	
Concrete 300 kg/m³	300 kg	400 l	800 l	<ul style="list-style-type: none"> • latrine slabs • foundation • ring beams • concrete rings
	6 x 50 kg bags	7 wheelbarrows	14 wheelbarrows	

(1 wheelbarrow = 60 l).

In case of doubt what proportions to use for concrete, keep it as simple as possible in all situations:

- Lean concrete: 1 part of cement, 4 parts of sand and 8 parts of gravel (parts in volume).
- Concrete: 1 part of cement, 2 parts of sand and 4 parts of gravel (parts in volume).

Preparation of mortar / concrete

- Prepare a clean, plane and level surface, like a screed, slab, metallic plate or wooden board.
- Put the required amount of sand on the surface.
- Deposit the required amount of cement on top of the sand heap (and not the other way around). Some prefer to put only part of the cement in the beginning and to add the remaining quantity once there has been a first mixture.
- Move the complete heap of sand and cement by shovelling it to a second spot on the surface. This is to get a mixture of the sand and cement.
- Repeat this action several times until a homogeneous colour is obtained (preferably at least three times). When concrete is prepared, the second time the heap is moved, it should be shovelled on top of the required amount of gravel. The complete heap, gravel included, should be moved at least another two times until a homogeneous colour appears, in order to ensure a good mixture.
- Make a crater in the middle of the cement - sand (- gravel) heap.
- Fill the crater with clean non-salty water.
- Mix the water immediately with the heap by pushing the crater's edges downwards in its centre.
- Keep on mixing in a similar way, and add little by little water until a homogenous and malleable paste is obtained. Don't add too much water because it can cause significant shrinking afterwards. This phenomenon occurs during the evaporation of the water. The particles will get closer to each other, causing thus a volume reduction of the mortar / concrete. Shrinking can be detected through the appearance of cracks. Other factors influencing shrinking are a too high cement dosage, the use of sand that is too fine and unclean, and working during the hot hours of the day.
- Use the mortar / concrete before it starts setting, meaning within half an hour following the introduction of the water to the mixture. During the setting (solidification period), the mortar / concrete will lose its plasticity (beginning of the setting), and finally won't be deformed anymore under finger pressure (end of the setting, around 4 hours after the water has been introduced to the mixture).

Remarks

■ When big quantities of constituents have to be ordered, their weight and volume have to be taken in consideration for transport reasons. The following table gives the approximate weight of:

Cement (loose)	Sand (dry)	Gravel (loose)
1200 – 1440 kg/m ³	1875 – 2595 kg/m ³	1745 kg/m ³

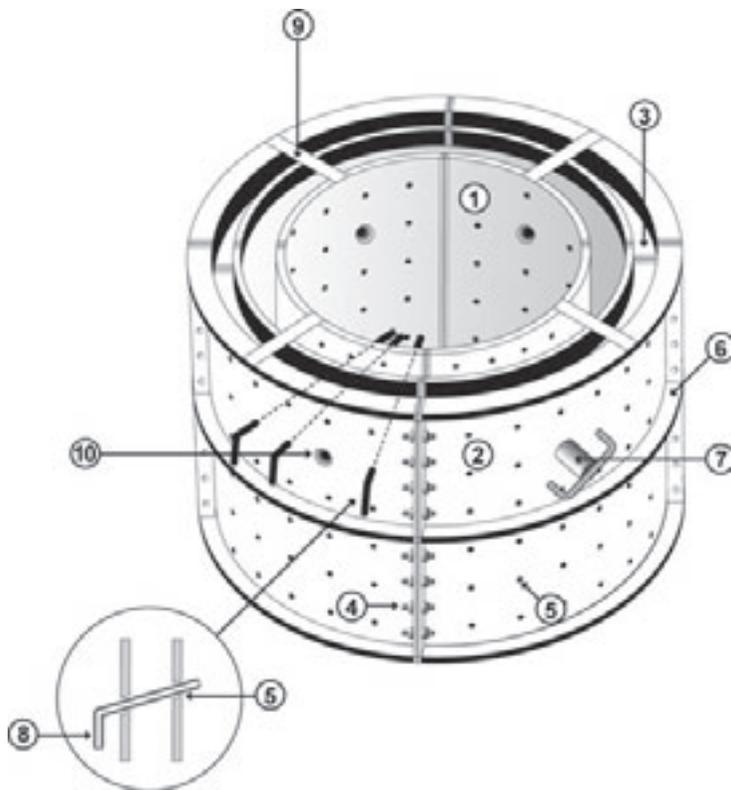
- The way cement is stored is crucial for its properties because it easily absorbs ambient humidity. If the storage is too long or uncared-for, a lack of resistance of the cement will occur: e.g. a 40% reduction in resistance can be measured after 12 months.
- Cement is expensive. Contractors sometimes try to reduce its proportion when preparing mortar or concrete, thus rendering the construction weaker.
- When considerable amounts of concrete are needed, it is recommended to use a concrete mixer.
- Concrete is very resistant against pressure, but not against tension. Therefore should concrete be reinforced with iron reinforcing bars at the places where it will be under tension.
- Once concrete has been cast, it should be “vibrated” by tapping on the mould, by ramming its surface with a wooden rammer or by poking (compacting) it rigorously with a reinforcing rod. A vibrating rod improves the removal of oxygen within thick layers of cast concrete.
- Concrete should be kept coffered and shored up during a certain time, depending on the size of the element (contact your technical referent if needed). This is to allow the hardening of the concrete, during which the resistance of the mixture will increase.
- Too much water in the mortar / concrete mixture will decrease its resistance and is therefore harmful. A minimum quantity of water must thus be added to the mixture. Adding some more water 30 minutes after the mortar / concrete has been prepared is absolutely prohibited.
- Setting and shrinking processes need hydration water, thus a quick evaporation of the water should be avoided. Mortars and concretes must therefore be watered twice a day during one week to obtain a correct shrinking process and thus a better mechanical resistance. Additionally, slabs and ring beams must be protected from wind and draughts with plastic sheeting as this would increase the evaporation rate and thus the risk of cracks. Walls must just be moistened by watering.
- If cement blocks can't be purchased locally, they can be made with a normal mortar composition. When a lot of cement blocks are needed, a fabrication team should be set up, consisting of one mason (supervisor) and six unskilled workers, divided in three posts:
 - 3 workers to prepare the mortar,
 - 2 workers for the moulding of the blocks and to remove them from the mould,
 - 1 worker for the watering of the blocks and for their stocking.
- A well-trained and organized team can produce up to 400 cement blocks per day. For this quantity, 16 bags of cement, 40 wheelbarrows of sand and 2 m³ of water (including watering) are needed. Foresee that 5 to 10% of the blocks will be lost (being broken).

T.B. 2.06 Fabricating concrete rings

Concrete rings are needed to line and protect hand dug wells. The concrete rings used for well intakes may be perforated during fabrication, or made of porous concrete. Porous concrete rings are preferred for use in decomposed rock, sand or gravel, but they are a lot more fragile than perforated reinforced concrete rings. The concrete rings used for the shaft and wellhead should obviously not be porous or perforated. Concrete rings may also have other purposes, such as making a spring box, a rainwater collection tank and pit reinforcements for latrines or sharps pits.

Construction

- Order, purchase or make locally (contact your technical referent) the needed moulds:
 - The mould set should be composed of two parts: the internal and external elements. Each of these elements is generally made of three or four sections which are bolted together. In order to be able to remove the inner mould once the cast concrete ring has hardened enough, a separate spacer element has to be available that will be removed first.
 - The moulds should be made of steel plate, at least 3 mm thick, reinforced with angle steel.
 - The inner diameter of a concrete ring (thus the outer diameter of the internal mould element) should be at least 1 m (strict minimum 0.8 m), so that a person can dig inside the ring. The external element should have an adapted inner diameter, permitting to make rings of 0.10 m thick.
 - Moulds are generally between 0.5 - 1 m high. A reduced height is compulsory for very big rings to keep their weight reasonable (e.g. a ring with a diameter of 1.60 m should maximal be 0.5 m high).
 - Tube-shaped templates for the moulds should be present, allowing to leave big openings in the concrete rings that will facilitate their lowering inside the well.
 - In case perforated concrete rings have to be made, the elements should have holes every 0.15 m and smooth metal pegs should be provided. Once inserted in the assembled moulds, the pegs should form an angle of 45° upwards from the outer to the inner side. This angle is important to limit sand entering into the well, once the perforated concrete rings are installed.
 - The mould set should be provided with two ground pedestals and a cover, all permitting to make positioning grooves (stepped concrete rings that fit together once installed).
- Make sure that all mould parts that will be in contact with the concrete are coated abundantly with a special oil for concrete casting (food graded) or an alternative (e.g. olive oil) to prevent concrete sticking to them.
- Position a ground pedestal on a flat, clean and solid surface (e.g. concrete slab).
- Bolt the internal mould sections and the spacer together, and install the assembly over the pedestal.
- Prepare a circular network of reinforcing bars around the inner mould, placed 0.1 m above the bottom and halfway between the internal and external mould elements.
 - Ordinary / perforated rings: the re-bars' length equals the mould's height minus 0.2 m, with a mesh size of 0.15 m x 0.15 m. Be careful not to have the re-bars positioned in front of the perforation holes.
 - Porous concrete rings should not be reinforced with iron re-bars.
- Bolt the outer mould sections together in a concentric way around the inner element, and introduce the tube-shaped templates. Insert also the oiled metal pegs if a perforated concrete ring is to be made.
- Prepare the concrete mix for the rings.
 - Ordinary and perforated rings should be made in similar concrete (at least 300 kg/m³; T.B. 2.05).
 - Porous concrete rings should have the same cement and gravel composition, but the amount of sand should be halved. This concrete should not be too wet either.
- Cast the concrete in between the inner and outer mould elements in layers of 0.25 m high, and position the cover when the mould is almost full of concrete, to create the upper positioning groove.
 - For ordinary and perforated rings, poke the concrete with a reinforcing bar to drive the air out.
 - Vibrate porous concrete rings by tapping on the mould, instead of poking (compacting).
- Remove the tube-shaped templates and potential metal pegs before the concrete sets completely (maximum 4 hours after the concrete has been prepared). Clean and oil all the templates and pegs.
- Remove all the mould sections about 24 hours after casting. The mould sections should be scraped and brushed to remove the concrete residues, and their contact surfaces oiled abundantly.
- Wash the concrete rings to remove all oil residues.
- Cure the concrete rings in the shade for at least 1 week, during which they should be kept damp (wetted twice a day and covered with jute sacking or plastic sheeting). Porous rings should cure longer than ordinary / perforated ones. They are more fragile and should be handled with care.



Key

Input

1. Internal mould element (minimum outer diameter 1 m)
2. External mould element (minimum inner diameter 1.2 m)
3. Cover to create positioning groove (alike ground pedestal)
4. Bolts and nuts
5. Holes to insert wooden or metal pegs (for perforated rings)
6. Reinforcing angle steel
7. Tube-shaped template
8. Wooden or metal pegs (for perforated rings)
9. Spacer (to maintain concentric distance between moulds)
10. Big holes for tube-shaped template

- Reinforcing bars (8 mm), metal wires
- Cement, sand and gravel
- Clean, non-salty water
- Ring mould set with all accessories
- Shovels, buckets, trowels
- Specific oil or olive oil
- Spanners, lump hammer, wire brush
- Plastic sheeting or jute sacking

Remarks

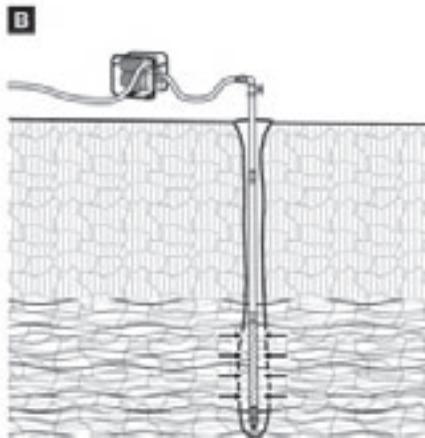
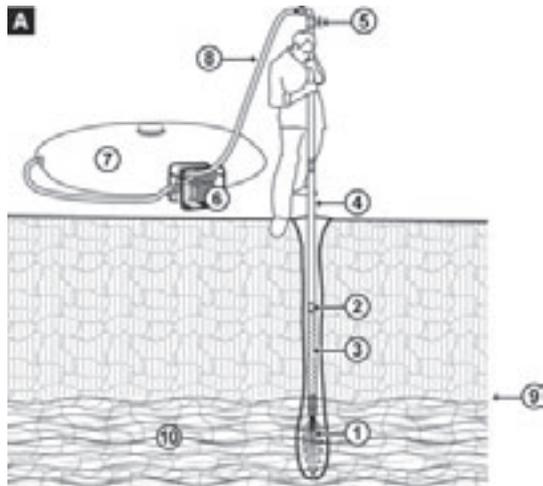
- In case of telescoping, porous concrete rings can be used for the intake, certainly in decomposed rock, sand or gravel. If telescoping is not used, porous concrete is prohibited for the intake because it is too fragile to withstand the weight of the complete concrete shaft (porous rings might crack over time).
- For rings that need to be bolted together (e.g. instable soils), three long metallic rods with thread on top should be inserted vertically into the concrete, with their parts sticking out of the ring as long as the height of the mould itself. Three metallic pipes with an inner diameter slightly bigger than the rods should be imbedded vertically in the concrete rings with their length exactly equal to the height of the mould (thus not sticking out of the ring). Make sure that the rods and pipes are put in an alternating way every 60°, assuring their alignment during the installation and bolting together of several rings.
- Moulds used for making well rings should not be coated with used engine oil, for health reasons.
- When the rings are produced in series for a program of well protection, it is recommended to use a sheltered area for curing and storing the rings.
- A tripod and pulley should be used to lower the rings safely into the well.

T.B. 2.07 Jetting

Jetting is a low-input “drilling” technique, suited to make rather shallow tube wells within unconsolidated soil formations, in particular sand. Lots of water is pumped by a simple surface centrifugal pump through solid tubes with limited diameter, which creates a jet that is introduced vertically into the soil. This will lead to the soil eroding underneath the jet and the water will bring the loose particles to the surface as the tubes sink further downwards. Due to its simplicity and rapidity, this technique can be very useful within emergencies at locations where the water table is relatively close to the surface (e.g. tube wells made in river banks). With the right equipment, it is possible to use the same tubes as raising main and the same surface centrifugal pump to develop and exploit the jetted well.

Operation

- Assemble the pre-jetting rod (½” GI pipe, 1 m long) and jetting rods assembly (self-boring strainer, rigid pipes, connections, valve, elbow and rapid coupling) as per figure A. Although jetting is possible without a self-boring strainer, it is a strongly recommended accessory. It concentrates the jet during the jetting operation and functions as a strainer when the flow will be reversed for developing and exploiting the tube well (if the water level is not deeper than 6 - 7 m at sea level). Kits, containing all these elements, are available.
- Make sure enough water will be available during the jetting procedure. In case the jetting takes place nearby a high yield river or a lake, the water can be taken directly from the source. When the yield or the available water quantities on the spot wouldn't be sufficient, a big reservoir (e.g. 15 m³ bladder) will have to be filled (potentially from an external water source) to cover the jetting needs.
- Install a surface centrifugal pump (e.g. motor pump) and perform all its checks according to the manufacturer's instructions.
- Connect with spiralled pipes the pump's inlet to the water supply and its outlet to the pre-jetting rod.
- Start the pump and rev it up in order to create a good jet at the pre-jetting rod.
- Introduce the pre-jetting rod vertically into the soil where the tube well will be installed and let it sink over its complete length (about 1 m), before removing it and stopping the pump.
- Replace the pre-jetting rod with the jetting rods assembly after having drained the spiralled pipes that are connected to the pump's outlet (weight reduction).
- Insert the jetting rods assembly in the pre-jetted hole and start lifting it in the vertical position. When GI pipes are used, it will take several persons to perform the lifting, due to the weight.
- Start the pump and rev it up in order to create a good jet, whilst the others keep the rods assembly in a vertical position.
- Guide the jetting rods assembly as it is sinking. In soft soil, take care that the assembly doesn't sink too fast as this could lead to the collapse of the jetted well. In case the jetting rods assembly doesn't sink, it can be wiggled a bit to remove some harder objects (e.g. small stones) blocking the rods from sinking. Under all circumstances, keep the pump working to remove the “cuttings”.
- Monitor the composition of the soil that comes out of the hole and take samples.
- Stop and disconnect the pump when the desired depth is reached (at least 3 - 4 m under the ground surface). The jetted well should be deep enough for the self-boring strainer to be completely in a water bearing layer with good permeability (e.g. sand).
- Stamp on the elbow of the jetting rods assembly if a self-boring strainer is used. As a result, the ball foot valve of the self-boring strainer should be closed.
- Connect the pump's inlet to the sunken jetting rods assembly, and its outlet to a long pipe draining the water away from the jetted well.
- Start the pump and keep it at low speed for 15 minutes. The fine (sand) particles will rise to be discarded, while the heavier particles (e.g. coarse sand, gravel) will remain down. This phase allows the creation of a filtering medium around the self-boring strainer.
- Monitor the yield and the turbidity (T.B. 2.13) of the water coming out of the jetted well.
- Rev up the speed of the pump and keep on monitoring the yield and the turbidity.
- Pulsate the speed of the pump and keep on monitoring the yield and the turbidity. After some time, the turbidity should normally decrease to levels under 5 (N)TU.
- Disinfect the jetted well once the obtained yield and turbidity are satisfactory (T.B. 2.03).
- Connect the jetted well via the pump to the water supply system (e.g. bladder).



Key

Input

A. Jetting procedure (self-boring strainer in jetting mode)

B. Developing / exploiting the jetted well (self-boring strainer in "suction" mode)

- | | |
|--|--|
| 1. Water jet | - Jetting kit |
| 2. Connections | - Motor pump kit |
| 3. self-boring strainer | - Reservoir (e.g. 15 m ³ bladder) |
| 4. Rigid pipes (2" GI or PVC) | - Chlorination kit |
| 5. Valve with elbow and rapid coupling | - Protective gear (e.g. heavy-duty gloves, boots, helmets) |
| 6. Motor pump | - (Temporary) fencing material |
| 7. Water supply (e.g. bladder reservoir) | |
| 8. Spiralled pipe | |
| 9. Water table | |
| 10. Aquifer | |

Remarks

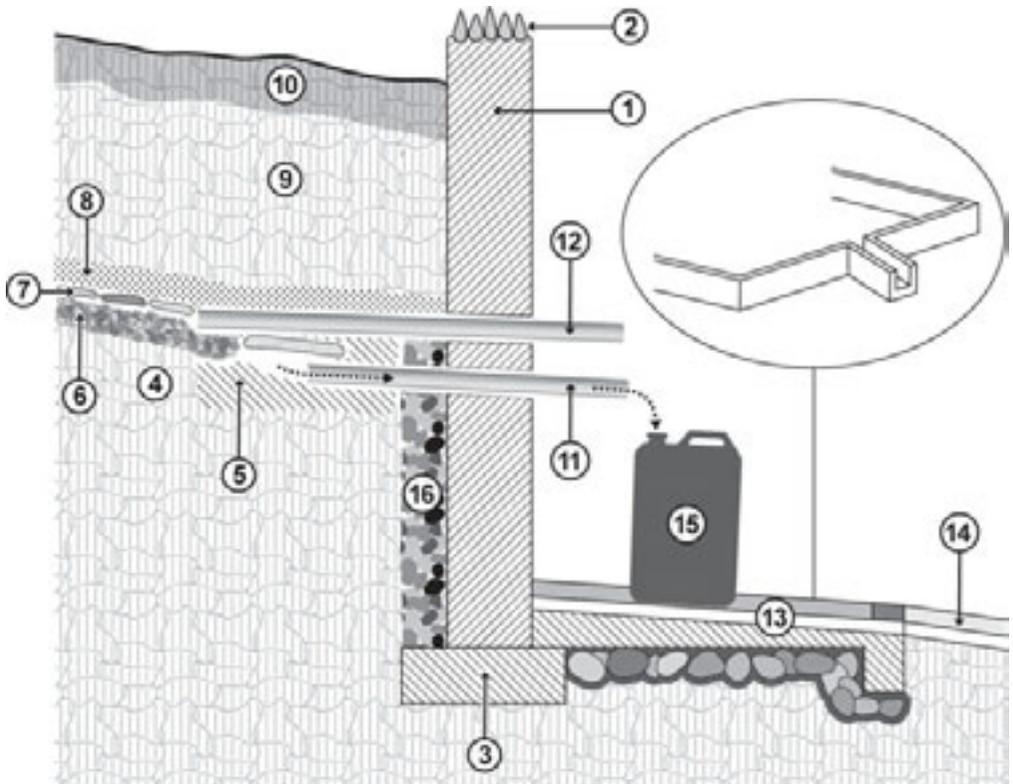
- The jetting technique doesn't work for consolidated soils. It will be able to pass through thin layers of gravel and clay, but the latter will not provide a high yield, even when it contains plenty of water.
- The sites where jetting will be performed have to be carefully chosen: the alluvial ground of river banks and around lakes might be a good area. Also jetting in or around a dry wadi can give good results, but be aware that the jetted well might be lost or at least flooded when the wadi fills up again.
- The jetted well should be at least 30 m away from latrines, and 50 m away from waste zones (with organic waste pits), landfills and cemeteries.
- The area where the jetting takes place should be fenced off in order to avoid accidents to bystanders. Unauthorised personnel should not be allowed on the site.
- The jetting rods are often made of galvanised iron (GI) pipes because of their strength. They have the big inconvenience however to be very heavy, which is not only a burden during their transport. It is also difficult to lift and keep the GI pipes in the vertical position during the jetting procedure. It will take several persons to lift a 2" jetting rod assembly of 5-6 m length, and potentially even ropes. One person will initially be needed to keep the self-boring strainer in the pre-jetted hole, while the others push the assembly in the vertical position.
- A (4x4) car can be used to push a 2" galvanised iron (GI) jetting rods assembly (longer than 6 m) in the vertical position. Besides the driver, one person will still be needed in the beginning to keep the self-boring strainer in the pre-jetted hole and at least two others to hold the assembly in position with long ropes.
- An alternative for galvanised pipes are rigid PVC tubes that resist high pressures (at least PN 10; T.B. 2.30). PVC pipes will bend a lot when long lengths are lifted from a horizontal to a vertical position, especially with the spiralled hoses connected. Introduce therefore short lengths of PVC pipe (e.g. 2.5 m) with threaded connectors on both sides (female on one side, male on the other). This means as well that the spiralled hoses coming from the pump and the elbow / valve will have to be disconnected each time a new rod is installed. Connect a short piece of spiralled pipe (e.g. 1m) to the elbow to ease the installation of every new rod.
- Special attention should always go to the jetting rods assembly not falling sideways, potentially causing damages and/or injuries. This entails as well that protective gear such as a hardhat, heavy duty gloves and boots should be worn by all personnel present during the jetting procedure. An overall is strongly recommended as well.
- Once the development of the jetted well is completed, it should be disinfected. This can be done by adding 10 l of 1% chlorine solution per m³ of water inside the jetting rods assembly (for 2" rods, this would mean pouring in 20 ml of 1% solution per meter of tube well under the water table level). After 12 hours, the hyper-chlorinated water should be pumped out of the jetted well and wasted until the Free Residual Chlorine concentration (T.B. 2.22) has dropped to 0.5 mg/l.
- Shallow high yield jetted wells, located in the neighbourhood of a surface water source (e.g. river), will often improve the turbidity enormously in comparison with the raw surface water. As such, the need for assisted sedimentation and/or filtration might be avoided (e.g. in emergencies). But its micro-biological quality might still be inadequate. Hence, such water should always be disinfected before consumption, according to the drinking water standards (T.B. 2.21).
- One motor pump can be connected at the same time to several jetted wells to increase the yield. However, the jetted wells should be spread out by at least 5 meters.
- Jetting can also be used to probe the soil rapidly to decide on the construction of (shallow) hand dug wells. Not only will the depth of the water table be known, some simple pumping tests on the jetted well can give information on the potential well yield that can be obtained.

T.B. 2.08 Protecting a spring

A spring needs to be captured and protected at its points of resurgence, also called the spring eye. A correct spring catchment will maximise the quantity of groundwater that can be collected, and prevent it from becoming contaminated when it nearly reaches the ground surface. A spring box can be added because it permits the sedimentation of heavy particles (e.g. sand) coming from the resurgences. The spring box could be constructed directly around the resurgences, but it is often cheaper and simpler to build or to install a separate one. A storage reservoir (potentially integrated within the spring box) is essential when the yield is low and groundwater also needs to be accumulated during the night to cover the real water demand.

Construction

- Clean and excavate the area around the spring to catch all the resurgences, in order to obtain the maximum yield. From the start, it will have to be decided if a separate spring box will be constructed downhill, or if the people will collect the water directly from the spring.
- For a separate spring box, excavate only around the spring eye until the impermeable layer is reached and foresee a trench for the foundation of the dam wall.
- For direct collection (as presented in the figure), similar excavation works need to be done. But the excavation works will have to be deeper in order to install a slightly sloping platform, where the users will be able to fill their recipients.
- Calculate the quantities of materials that are needed (e.g. concrete, stones, bricks) according to the size of the spring and the local construction means. The amounts of materials also depend on the decision to build a spring box nearby the resurgences or not.
- Divert the spring water during all the construction works.
- Make a clay or concrete (150 kg/m³, T.B. 2.05) bowl-shaped slab just above the trench for the dam wall foundation, but below the spring eye.
- Construct the dam wall foundation within the trench, using concrete (300 kg/m³) or masonry-work.
- Erect the dam wall with masonry-work without forgetting to insert the outlet and overflow pipes;
 - The outlet pipe (galvanized iron) should be imbedded with clay or mortar in the bowl-shaped slab and slightly inclined along the slope of the hill. The bowl-shaped slab should be covered with a large stone or a concrete slab.
 - The inlet of the overflow should be just underneath the level of the spring eye and its pipe (with a bigger diameter than the outlet pipe) inclined along the slope of the hill.
- Make the dam wall watertight on the inside (side of the spring eye) with a clay coating or two layers of cement plaster (each 10 mm thick; T.B. 2.05). The second layer should only be applied once the first one has dried. Pay particular attention around the pipe passages. Put preferably also one layer (10 mm) on the outside of the dam wall.
- Imbed sharp stones on top of the dam wall to discourage people sitting or standing on it.
- Backfill the remaining gap in between the dam wall and the excavation with small stones so as to avoid erosion and collapse.
- Place clean pebbles (gravel) between the bowl-shaped slab and the spring eye in order to allow the spring water to flow freely.
- Cover the pebbles with large stones (or concrete slabs) and a clay layer (at least 0.1 m thick) that continues until the dam wall. This clay layer prevents the spring being contaminated by surface or runoff water. It is recommended to pour a 1% chlorine solution on top of the bowl-shaped slab and the pebbles, before the protective clay layer is applied.
- Backfill the remaining part behind the dam wall with the excavated soil, and cover with topsoil.
- Make a concrete floor just underneath the dam wall. This concrete floor will avoid erosion (e.g. caused by the spring overflow) and will provide a clean area in case the people will collect water directly at the outlet pipe.
- Make a drainage channel to drain the spilled / overflow water away.
- Make also drainage canals above the catchment area leading the runoff water around the spring. This prevents the runoff water damaging or contaminating the resurgences.
- Install a fence (e.g. bushes) around the site, with a radius of at least 10 m to avoid access to animals that can contaminate and/or damage the spring area.
- Plant short rooted vegetation (e.g. grass) on top of the spring catchment to stabilise the soil and to protect it against erosion.



Key

1. Impermeable dam wall
2. Sharp stones
3. Foundation of the dam wall
4. Impermeable soil
5. Bowl-shaped slab
6. Clean pebbles
7. Large flat stones or concrete slabs
8. Clay layer
9. Backfill soil
10. Topsoil
11. Outlet pipe
12. Overflow pipe (case depending)
13. Cemented platform
14. Drainage channel
15. Water container
16. Backfilling (gravel)

Input

- Concrete and/or fired bricks / cement blocks / big stones
- Cement, sand, gravel, pebbles, clean non-salty water
- Clay
- Large flat stones (or concrete slabs)
- Top soil and grass
- 1½ or 2" galvanised iron outlet pipe(s)
- 2" galvanised iron overflow pipe(s)
- Fence material
- Digging equipment (shovels, hoes, pick axes)
- Masonry tools
- Plumber tools

Remarks

- It is important, before any construction work starts, to do a sanitary survey to identify the pollution risks, and to determine the real water demand. Before the start-up of a big spring construction, specialised literature should also be consulted and a site-specific plan drawn.
- A real spring should have a constant water temperature. If this is not the case, it is probably surface water that went underground somewhere uphill and is re-emerging. The yield of such a re-emerging “spring” will most often rise rapidly if it rains.
- Be careful not to divert the spring in another direction or into another fissure when digging around it. Terracing should start at the point where the water comes out of the earth. Dig by working upstream the water bearing layer, while ensuring that the spring water can flow freely away.
- The excavation should continue until the impermeable soil layer is reached. This is the level from where the spring water should be captured, thus it also indicates where the outlet pipe should be installed.
- In case the underground wouldn't be (completely) impermeable (e.g. fissures), the bottom of the excavation should be made watertight by plastering it with a layer of clay or lean concrete.
- For larger springs with a yield higher than 30 l/min, several outlet pipes will be required. For small springs with a yield lower than 20 l/min, one 1½” outlet pipe is sufficient.
- Never let the water level inside the catchment rise above the spring eye as this could produce a back pressure which can make the flow emerge elsewhere. Therefore is the correct level of the overflow pipe crucial for the good functioning of a spring, meaning that it should never be positioned above the level of the spring eye.
- In case the water collection is done directly at the outlet pipe, there should be a sufficient height difference in between the outlet pipe and the platform for (large) water recipients to fit in between (0.5 m is often enough).
- When a spring box is added to an existing catchment where water is collected directly, the outlet pipe should preferably be covered with soil. Therefore will it be necessary to backfill the platform until the outlet pipe is covered and a new concrete floor should be constructed to drain the overflow water away without causing erosion.
- A (separate) spring box is recommended because it will permit heavy particles coming from the resurgences to settle down, which will protect the pipeline downhill from getting clogged and/or people having dirt in their water. It is recommended to have the spring box divided into two compartments by a ¾ high wall. The particles will settle in the first compartment and the water flowing over the wall into the second compartment should be exempt of dirt. The settled particles will have to be drained once in a while from the spring box, therefore a separate drainpipe with valve (besides the outlet and overflow pipes) will have to be foreseen.
- A spring box can also function as storage capacity (during the night). This is essential in case the spring has an insufficient yield to cover the actual water demand with daytime collection only. However, it might be difficult or even impossible to transport all building materials or a pre-fabricated reservoir (e.g. plastic) to the spring site. A storage reservoir can then be located nearby the consumption area (e.g. village, health structure). Another advantage of having the reservoir close to the consumption point is that it is easier to chlorinate the water (to protect it from post-contamination). Often a combination of a relatively small (separate) spring box at the catchment and a storage reservoir nearby the consumption point is the preferred option for long-term use.
- Once the construction is finished or maintenance works have been done, the spring box / reservoir should be disinfected. This can be done in a similar way as hand dug wells are disinfected (T.B. 2.03, technique A), at least once a year.
- A spring will require a minimum of maintenance; the collection area and drainage channels should be kept clean and vegetation should be kept under control not to damage the structure (e.g. plants with long roots starting to grow on the spring catchment should be eliminated).

T.B. 2.09 Rainwater harvesting

Rainwater in non-industrialized and non-urban areas presents normally good quality characteristics. Although its variability along the seasons is generally important, rainwater harvesting can be interesting to cover the whole water demand, or to complement other water sources that are insufficient in quantity and/or quality. Rainwater can be collected from any clean surface, with roof catchments being used most often. The rainwater is then transferred to a tank via gutters. The contamination of harvested rainwater comes primarily from the first rains, rinsing away the accumulated dirt on the roof. Correct techniques of rainwater harvesting will remove this contamination first before the water is stored.

Demand / supply analysis

- Determine the total daily demand (m^3/day), based on the number of consultations and number of beds of a health structure for instance.
- Verify the total ground surface covered by the roof (including the eaves) that will be used for the rainwater collection; this "horizontal" collecting roof surface (R) equals the length (L) x breadth (B).
- Collect monthly rainfall data for the region. This data can be found at meteorological stations (e.g. at airports), or potentially in universities and on the internet (e.g. www.worldclimate.com)
- Calculate the average daily supply based on the annual rainfall and the collecting roof surface according to the formula:

$$\text{ADS} = (\text{AR} \times \text{R} \times \text{C})/365$$

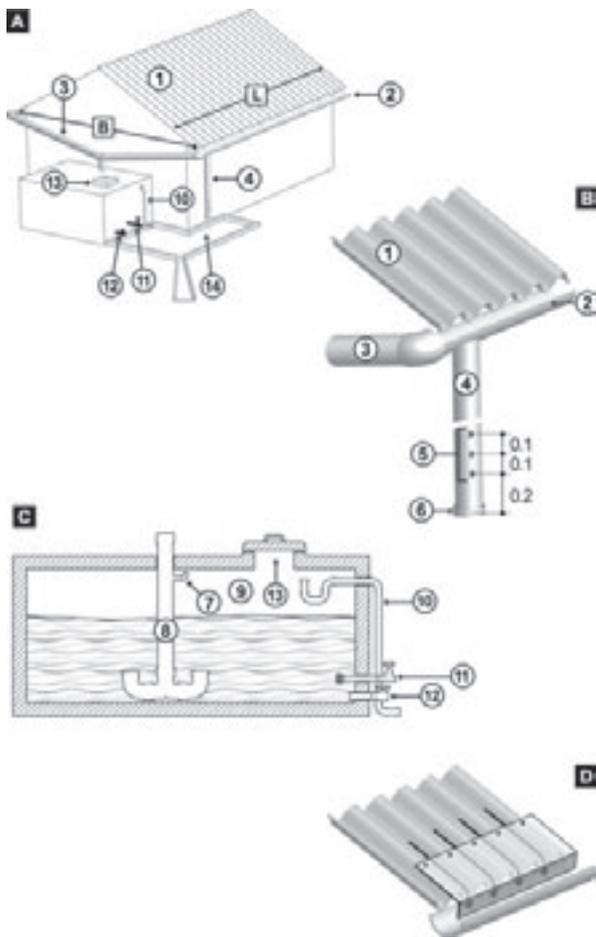
With ADS (m^3/day) = average daily supply

AR (m) = annual rainfall

R (m^2) = collecting roof surface (plan area)

C = runoff coefficient (it considers mainly evaporation, wetting and leakages, and it depends on the roof material and its age; apply a coefficient of 0.8 – 0.9 for tiles, 0.7 - 0.9 for corrugated metal sheets and 0.7 - 0.8 for plastic sheeting)

- Compare the total daily demand to the average daily supply (ADS). If the supply is higher than the demand, rainwater harvesting can **fully** be used to provide sufficient water over the whole year, as long as there is enough storage capacity. If the supply is lower than the total demand, the collecting roof surface should be increased, augmenting the costs significantly, or the rainwater will only be used:
 - Occasionally: the very limited storage capacity only permits to cover the demand with rainwater when it's raining; one or two days without rain means that another source has to be used. This system can be useful in areas with a uniform rainfall pattern, with a limited investment.
 - Intermittently: the storage capacity is such that the demand is covered during the whole rainy season, but during the dry season another source will have to be used. This system can be useful in areas with a long rainy season.
 - Partially: the storage capacity permits to cover the demands partially over the whole year (e.g. good quality water for drinking and cooking), while the other needs (e.g. laundry) have to be covered with another source of lesser quality (or the other way around). This system can be achieved for areas with a uniform rainfall pattern by a relatively small storage capacity, but needs a big reservoir if the pattern isn't uniform.
- Estimate the needed reservoir size.
 - Occasional: its storage capacity should be for 1 or 2 days, the latter certainly for health structures.
 - Intermittent: its capacity should be able to cover the total daily demand over all the days the rainy season lasts. Be aware there might be some days it doesn't rain, even during the rainy season.
 - Partial: its storage capacity should cover the specific demand (e.g. drinking) over the whole year.
 - Full: the storage capacity should cover the total demand over the whole year, knowing there will be months with a supply surplus and others with a deficit. The calculation of the needed reservoir capacity falls outside the scope of these guidelines (contact your technical referent).
- Make a final choice to invest in rainwater harvesting systems or to exploit other sources, depending on:
 - The demand / supply analysis: high demands can significantly increase the investment costs for the collection and storage capacity, as do long dry seasons.
 - The comparison between the development and operation costs of alternative water sources and the costs of the rainwater harvesting system, including storage costs.



Key

Input

- A. Rainwater catchment system
 B. Detail of a roof washer (pipe system)
 C. Detail of a collection reservoir
 D. Detail of a deflector on a gutter system
1. Roof (plastic, metal or tiles)
 2. Gutter
 3. Down-pipe towards the reservoir
 4. Descending pipe towards the roof washer
 5. Draining holes (2 mm diameter)
 6. Removable end cap of the roof washer
 7. Small ventilation pipe
 8. Inlet pipe of the reservoir with elbows
 9. Water reservoir
 10. Overflow pipe with siphon and screen
 11. Screened outlet
 12. Drain of the reservoir
 13. Manhole with a removable cover
 14. Evacuation for dirty water and overflow

- Electrical drilling machine or hand drill with bits
- Rounded and half-rounded files
- 4" PVC pipes, elbows, Tees, caps
- PVC glue and de-greaser
- Gutters (e.g. halved PVC pipes)
- Supports for pipes and gutters
- Saw and hammer
- Other carpentry and masonry tools
- Nails and screws
- Screens
- Reservoir (size according to the needed volume)
- Roof washer (size according the volume needed)

Installation

Traditional system

- Install a water reservoir with the correct size. The reservoir can be constructed in masonry-work, concrete, or ferrocement (T.B. 2.38), or it can be prefabricated (e.g. plastic, fibreglass). It should be a completely closed reservoir with a covered manhole. It should have an inlet at the top, a sludge drainpipe with a valve, an outlet with an individual tap or a connection to a distribution system via a valve, and an overflow that is covered with a mosquito screen. Its location should be as close as possible to the roof where the rainwater is harvested. A correct evacuation system should be foreseen for the overflow and the spilled water from the tap, with the aims to avoid stagnant water and erosion around the reservoir.
- Prepare a roof washer system (also named first or foul flush device) to avoid that the first rains rinsing the roof would enter into the water reservoir. Several foul flush devices exist, like factory made models based on the principle of a vortex which keeps the dirt particles in suspension, while only clean water can pass into the reservoir. It is also possible to make some simple systems locally, like:
 - a vertical pipe with a diameter of at least 4" descending at every 10 m of gutter length, closed at the bottom with a watertight but removable cover (as per figure B). The first (dirty) rainwater will be collected in the descending pipe until it is full, and then clean rainwater will overflow into the reservoir. A small hole (2 mm diameter) should be made about 0.2 m above the removable cover, and another two on top of each other with a distance of 0.1 m (as per figure B). These holes will allow the descending pipe to drain completely once the rainfall stops. In this way, this simple but automatic device will be ready again for the next rainfall.
 - a grease trap alike design (T.B. 4.04, model A with elbow and T-piece) placed on top of the water reservoir, in which the dirt particles will settle. A screen (e.g. metallic mosquito netting) can be added in the middle of the device to stop leaves from getting into the water reservoir. Some small drain holes should be foreseen again to empty this roof washer automatically.
- Install the gutters at the edge of the roof, with a 0.2 to 1% slope towards the roof washers and down-pipes. The gutters can be factory made (e.g. PVC, metal) or locally made of a cut-in-half PVC pipe or a galvanised metal sheet folded in a rectangular section. The gutters must be solidly fixed in order to withstand a sudden and violent water influx, like is frequently occurring in tropical areas. In order not to lose too much rainwater during heavy rainfall, it is recommended to install deflectors at the edge of the roof (as per figure D).
- Connect the gutters with the roof washers and the down-pipes. The connections should be watertight.
- Foresee also additional leaves separators. These can be cones with holes that are installed in the gutter, one over each inlet of the descending and down-pipes.

Alternative for emergencies

- Rainwater can also be an interesting (additional) source for (acute) emergencies. Following are two ways of installing a simple emergency rainwater harvesting system:
 - Suspend a piece of plastic sheeting in a large U-shape to form some kind of a big gutter, which is hanging with its lower side inside an open reservoir (T.B. 2.35; 2.38). The upper corners of the plastic sheeting are potentially connected to an existing roof. If the roof is of poor quality or in case of a tent, new plastic sheeting can be used to cover it.
 - Install on a gentle slope several complete rolls of plastic sheeting overlapping each other (e.g. 5 rolls = 60 m x 16 m catchment area), with a big gutter at the lower end. A surface pump can transfer the rainwater that is collected inside the gutter to a reservoir for disinfection and storage.
- For these temporary solutions, it won't be possible to install an automatic roof washer. Thus the first rains will have to be discarded by draining the dirty water away.

Operation and Maintenance

- Disinfect the water reservoir and other cisterns of the rainwater harvesting system before they are commissioned and after they have been cleaned. This can be done in the same way as described for wells (T.B. 2.03, technique A). Every 2 – 3 years, they should also be examined for sludge accumulation.
- Fill the reservoir with potable water from another safe source after cleaning and disinfection works have taken place. Otherwise, it will take too long before the reservoir is filled up again with rainwater, certainly during the dry season.
- Clean the roof washers frequently to avoid accumulation of materials like leaves or sand that will block the drain holes. The gutters and the leaves separators must be cleaned regularly too.

Remarks

- In urban and/or industrialized areas, it is strongly recommended not to use rainwater for drinking, feeding (cooking, washing dishes) and personal hygiene activities because the atmospheric pollution has an important impact on the water quality. In these contexts, it should thus be avoided to implement rainwater harvesting systems, unless the water will only be used for other purposes (e.g. flushing of toilets, laundry).
- The amount of rainwater that can be harvested is relatively limited. If partial and full systems are required, substantial investments will be needed for the roof and the storage reservoir. In order to reduce the needed storage capacity, the rainwater should be harvested on all the available roofs. Under certain circumstances, it will be cheaper to construct an additional roof (which in a health centre could be used as a waiting area for the patients for instance) than to build a big reservoir.
- The slope of the roof itself and its actual number of square metres are not important to determine the roof surface. It is only the ground surface covered by the roof that should be determined.
- Painted or corroded iron sheets and thatch should be avoided for rainwater harvesting. Good quality galvanized iron or plastic sheets and tiles are the preferred choice for rainwater collection. Existing asbestos-cement roofs in good condition could be considered as well. The asbestos-cement micro-fibres don't represent any health risk when swallowed. However, they are very dangerous when inhaled. Thus the risk would be a lot higher to remove the existing asbestos-cement roof to be replaced by another material than using it directly for rainwater collection. Serious attention should still be given not to cut, break or drill in the existing asbestos-cement sheets during the installation of the gutters.
- In case rainwater is the only source of water, the reservoir size should be calculated correctly, based on the monthly rainfall data. Extreme over-sizing is too expensive and under-sizing will lead to a water shortage at the end of the dry season.
- The storage reservoir must imperatively be closed to protect the harvested rainwater from any external contamination. A manhole with a well closing lid is essential however to permit regular maintenance. The overflow of the reservoir should always be equipped with a screen to avoid that vectors would breed inside.
- Roof washers are essential, certainly if the harvested rainwater will be used as drinking water without treatment (although chlorination is always recommended for health structures). Their capacity must be sufficient for the roof to be cleaned and for the harvested rainwater not to contain impurities anymore. Their capacity should be calculated according to the surface of the roof and the environmental conditions; e.g. intensity and frequency of the rainfall, surrounding vegetation. A rule of thumb for correct rinsing is to foresee about 1 l/m² of roof surface, although this will not be possible for areas with limited rainfall. At least 5 l of the first rains need to be discarded for roofs of small houses, whereas at least the first 25 l can't be used for medium sized buildings (e.g. health centres with a roof surface of 150 m²).
- The drain holes of a roof washer have to be small not to interfere too much with the system filling up, even during light rainfall. However, due to their small size, they might get clogged rapidly which will hamper the automatic drainage of the roof washer. Therefore is a very frequent cleaning of the device of utmost importance.
- In areas where avian flue is present or suspected, it is strongly recommended to chlorinate the rainwater to a free residual concentration of at least 0.5 mg/l, after a minimum contact time of 30 minutes with the water at a pH < 8.

T.B. 2.10 Water analysis

Potable water should be absent of pathogenic organisms and have low concentrations of toxic chemicals. Unfortunately, these two criteria cannot be assessed by simple tests. There is no direct relationship between the appearance of a water sample and its drinkability; for example, a cloudy sample may be safe, whereas a clear sample may be both chemically and microbiologically contaminated. The presence of pathogenic organisms is a more frequent and acute problem than the presence of chemical substances at toxic concentrations in non-industrialized and in non-intensive agricultural areas.

Microbiological analysis

The pathogenic organisms which may be present in water are too numerous and too various to be identified individually in practice. As their presence is mostly linked to faecal contamination (except for e.g. Guinea worm), it is preferable to look for organisms that are “indicators” of this pollution. These indicators should be universally present in large numbers within the faeces of humans and other warm blooded animals, should be readily detectable with relatively simple methods and should not grow in natural waters.

The indicator organism of choice for (recent) faecal pollution is the *Escherichia coliform* (*E. coli*). Thermo-Tolerant Coliforms (TTC) can also be used as an alternative in many circumstances and certainly under field conditions, because a very high percentage (more than 80 %) of the TTC's are *E. coli* anyway. The kind of indicator that will develop during a bacteriological analysis depends mainly on the culture media and the incubation temperature.

Water for human consumption should not contain indicator organisms. The presence of *Escherichia* or Thermo-Tolerant Coliforms in water indicates the probable presence of pathogenic organisms, where their absence indicates the possible absence of pathogens, but is no proof of this. Certain pathogens like protozoa and some enteroviruses are more resistant than faecal coliforms to unfavourable environmental conditions and disinfectants like chlorine.

The count of *Escherichia* or Thermo-Tolerant Coliforms per 100 ml gives an indication of the degree of faecal pollution. Where the ideal is set at 0 *E. coli*/100 ml of water, a count of up to 10 *E. coli*/100ml may be admissible without treating the water. Counts above this level require at least a disinfection (e.g. chlorination) that will have to be preceded by other forms of treatment when the turbidity is high (T.B. 2.12). Following table gives an appreciation of the health risk related to the amount of coliforms that are present in a 100 ml water sample.

Health risk	Class <i>E. coli</i> or TTC/ 100 ml
None – conform	0
Low risk	1 – 9
Intermediate risk	10 – 99
High risk	100 – 999
Very high risk	≥ 1000

Bacteriological analysis are mostly performed by means of the membrane filtration method or the Most Probable Number (MPN) method. Both methods have their advantages and inconveniences. The membrane filtration method gives direct and more precise results (on non-turbid water) when performed by experienced people, where the MPN method is less but sufficiently accurate and a lot easier to perform and to interpret. Both methods can be implemented as well under laboratory as under field conditions.

When water is (mass) distributed via taps, it should normally be treated, at least with chlorine. In these cases, the indicators (e.g. *E. coli*) will be eliminated by the disinfectant and the count of coliforms is less relevant. Where disinfection isn't possible, a bacteriological analysis is strongly recommended, even in some acute emergencies (e.g. a hand pump installed on a well that has been flooded). A positive count of coliforms in the water indicates the presence of (faecal) pollution. For chronic emergencies and certainly for stabilised situations, the source of the pollution should be found and prevented first, rather than starting to treat the water. For accidental events, the pollution should be retrieved if possible and preventative measures installed.

Chemical analysis

The chemical analysis method differs for each element that needs to be examined. As each element requires specific tests, refer to more specific literature. These tests and their interpretations are to be carried out by properly trained personnel. Based on experience, appropriate analysis must be carried out, preferably by the national authorities:

- when a long-term water supply is being planned and/or
- when chemical pollution is suspected (intensive agricultural area, industries).

The way the water samples for chemical analysis have to be taken is presented in T.B. 2. 11.

Physical analysis

Two main physical water characteristics are to be measured, certainly when chemical treatment like coagulation / flocculation (T.B. 2.15) and/or chlorination (T.B. 2.21) is required:

Turbidity

indicates the amount of suspensible particles present in the water. Turbidity is commonly expressed in (Nephelometric) Turbidity Units or (N)TU. It is considered that a turbidity under 5 NTU permits the “most effective disinfection possible” with chlorine, at least under field conditions (T.B. 2.21). A turbidity up to 20 NTU is still acceptable to chlorinate drinking water during the acute phase of an emergency. The turbidity might also be an important factor for the acceptability by the consumers. T.B. 2.13 presents the detailed procedure to measure turbidity.

pH

is a logarithmic scale of the hydrogen ion (H^+) concentration and indicates in practice if the water is acid (<7), neutral ($=7$) or basic (>7). Although the pH has no direct (health) impact on the consumers, it is one of the most important operational water quality parameters as it has an influence on some chemical water treatment procedures and on the corrosion / incrustation of the equipment (e.g. pumps, pipes). T.B. 2.22 presents the detailed procedure to measure the pH with a pool tester.

Remarks

- Bacteriological and/or chemical analyses are not always necessary. It is generally much more important and useful to do a sanitary survey concerning amongst others; the origin of the water, the protection of the water point, its location in relation to defecation areas, cemeteries and waste zones, the protection of the water during transport and storage. Such a survey will often make it possible to determine if the water is polluted, or has strong chances of getting polluted at one time or another. Analyses only give an indication of pollution at the precise moment of sampling, and not of the potential risk of pollution. However, it can be relevant to do a bacteriological analysis of a well protected water source: e.g. in case there is a sudden increase of faecal-oral diseases.
- The health risk due to toxic chemicals in drinking water differs from that caused by microbiological contaminants. There are few chemical contaminants of water that can lead to acute health problems, except through massive (accidental) contamination of the supply. Most chemical contaminants of drinking water cause adverse health effects after prolonged periods (years) of exposure.
- In case water treatment is performed with chemicals, field test kits (for iron / aluminium or chlorine residual measurements) should be available to do a regular follow up of the treated water.
- Laboratories that can perform bacteriological and chemical analysis can often be found in the capital of low-income countries, and also in water treatment plants or in breweries. The main problem, in particular for bacteriological analysis, is to get the water sample on time in the laboratory. Samples should reach the analytical laboratory within the hour of sampling if they are kept at ambient temperature, or within 6 hours if they are kept at a temperature between 4 and 6 °C (but not frozen).
- Always work with clean hands (washed with water and soap) when performing sampling (T.B. 2.11) and water analysis. Any contamination by dirty hands can / will distort the results.
- When a new water source is put into service and if the infrastructures are available, the water sampling and analysis should be undertaken by the appropriate (national) authorities, according to the national standards. In this way, the local government will be involved in the process and the responsibility transferred to them. In acute emergencies however, this procedure might be more complicated.

T.B. 2.11 Water sampling

In order to obtain correct results from the water analysis, it's important to strictly respect the whole procedure, starting from the moment a water sample is taken. The way the sampling is done depends on the water "source", but differs also slightly whether it is for bacteriological or chemical analysis. It is recommended to double all samples to rule out as much as possible any mistakes.

Sampling Techniques

Sampling for bacteriological analysis

A. From a tap: step 1 - 8

- Clean the tap with an unsoiled cloth impregnated with alcohol or soap.
- Let the tap run fully for about 30 seconds.
- Flame it with a pad soaked in alcohol if it's a metallic tap.
- Let it run fully again for 30 seconds.
- Remove the protection (seal) from the sterile bottle and take off its cap. Don't put the cap down where its inside could get contaminated.
- Take the water sample.
- Replace the cap and the protection (seal) without touching the inside of the bottle / cap, nor the water.
- Label the sample bottle and record the essential information in a notebook.

B. From a water course:

- Remove the protection (seal) from the sterile bottle and take off its cap. Don't put the cap down where its inside could get contaminated.
- Turn the bottle upside down and introduce it in the river.
- Turn the bottle upright when it is at about 0.2 m under the water surface. This should be done in such a manner that the inlet is facing the current (water flow direction), in order to avoid that the water sample gets contaminated by your hand.
- Let the bottle fill up completely with water and take it out of the river.
- Replace the cap and the protection (seal) without touching the inside of the bottle / cap, nor the water.
- Label the sample bottle and record the essential information in a note book.

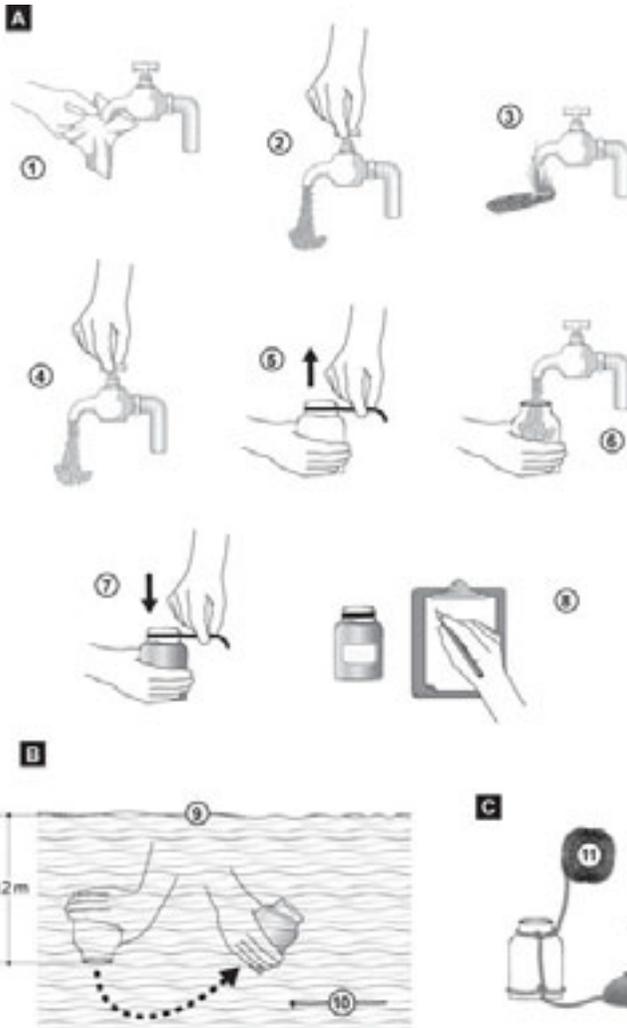
C. From a well:

- Attach a disinfected weighting ballast and string to the closed sterile bottle.
- Remove the protection (seal) from the sterile bottle and take off its cap. Don't put the cap down where its inside could get contaminated.
- Lower the bottle in the well until it is about 0.2 m under the water surface. The weighting ballast will help the bottle to sink.
- Lift the bottle carefully to the surface again.
- Replace the cap and the protection (seal) without touching the inside of the bottle / cap, nor the water.
- Remove the weighting ballast and string from the closed bottle.
- Label the sample bottle and record the essential information in a note book.

Sampling for chemical analysis

The sampling techniques for chemical analysis are similar to those for bacteriological analysis. However, even if it is still necessary to let the tap run for about 30 seconds, there is no need to respect the measures for sterile sampling (e.g. sterile bottles, flaming of the tap). A water sample for chemical analysis requires at least 2 glass or plastic bottles of 1 to 1.5 l (e.g. mineral water bottles), which must be clean and airtight.

- Prepare the bottles to collect the water sample:
 - Attach a rinsed weighting ballast and string to the closed bottle if the sample needs to be taken from a well.
 - Remove the cap from the bottle.
 - Rinse the cap and the bottle 3 times with the water to be analysed, according to the sampling techniques described for bacteriological analysis.
- Fill the bottles right to the top according to the sampling techniques described for bacteriological analysis and put their cap back on (remove the weighting ballast and string from the closed bottle if necessary).
- Label the sample bottle and record the essential information in a note book.



Key

- A. Sampling from a tap (bacteriological analysis) steps 1 - 8
- B. Sampling from a water course
 - 9. Water surface
 - 10. Current
- C. Sampling from a well
 - 11. String coil
 - 12. Weighting ballast (e.g. stone)

Input

- Bacteriological
 - 2 sterile 100 ml bottles per sample
 - Cotton wool / forceps (hair tweezers)
 - Alcohol and lighter (if tap)
 - Cool box and icepacks
- Chemical
 - 2 x 1 l glass or plastic bottles per sample
- Common
 - Thermometer
 - Marker pen for labelling
 - Notebook and pen
 - String and weighting ballast (if well)

Remarks

- Always work with clean hands (washed with water and soap) during sampling and water analysis. Any contamination by dirty hands will distort the results.
- The described measures for sterile sampling are not necessary for chemical analysis, but are absolutely essential for bacteriological analysis.
- Sterile 100 ml sample bottles can potentially be obtained from a laboratory or from the sterilisation department of a hospital. An alternative is to purchase sterile bottles or sterile single use sachets. If these solutions aren't possible, it is still possible to sterilise the bottles yourself according to the following steps:
 - Foresee at least 2 x 100 ml bottles per sample. Glass and polypropylene (PP) bottles can be sterilised, but polyethylene (PE) and PVC bottles won't resist the temperatures that will be reached in the autoclave.
 - Remove the cap from each bottle.
 - Immerse the bottles and the caps in a 0.1% chlorine solution for 15 minutes.
 - Rinse the bottles and caps with clean water.
 - Wash the bottles and caps with clean water and soap.
 - Rinse all of them with clean water and dry them.
 - Pack the bottles and caps together in a double layer of crêpe paper (don't put the caps back on the bottles, to allow the steam to enter).
 - Put the package upside-down in the autoclave, in such a manner that the opening of the bottles are pointing downwards.
 - Sterilise the package at 1.05 bar (121 °C) for 20 minutes according the instructions of the autoclave's manufacturer. This should preferably be done by an experienced person (e.g. in a health centre).
 - Keep the crêpe paper package at a safe place until the sterile bottles are used, which should be within the 2 weeks following the sterilisation (if not, the procedure should be repeated).
- If there is no autoclave, the bottles may be "sterilized" by boiling:
 - Place each bottle and its unscrewed cap in clean water and let it boil for 20 minutes.
 - Take them out of the water after 20 minutes of boiling, and let them cool, whilst protecting the opening with flamed aluminium foil or a sterile compress.
 - Use the bottles as soon as possible.
- Never touch the inside of the sterilized bottle / cap. When sampling, hold the cap by the outside; never put it down unless it is upside down. It is better, for security and reliability, to double each sample.
- The weighing ballast should be disinfected before the water sample is taken: remove all the potential dirt, boil it for 20 minutes or flame it with alcohol.
- For a bacteriological analysis of water that has been chlorinated, a sodium thiosulphate solution has to be added to each sampling bottle before sterilizing. This product will neutralize the chlorine of the water sample, which would otherwise affect the results. Single use sterile sachets with integrated sodium thiosulphate are also existing. Contact your technical referent for more information.
- Certain chemical tests require special sampling. Enquire about these with your technical referent.
- Mark the following on each water sample (and keep a copy in a notebook):
 - an identification number, the sampling place and the water source type (as accurately as possible);
 - the date and time of sampling and dispatch;
 - the substance(s) or organism(s) to be identified; specific techniques wanted;
 - treatment, if any, of the water (treatment product and dose);
 - water temperature at the time of sampling (if possible).
- Laboratories that can perform bacteriological and chemical analysis can often be found in the capital of low-income countries, and also in water treatment plants or in breweries. The main problem, in particular for bacteriological analysis, is to get the water sample on time in the laboratory. Samples should reach the analytical laboratory within the hour of sampling if they are kept at ambient temperature, or within 6 hours if they are kept at a temperature between 4 and 6 °C (but never frozen).
- In case it isn't possible to get the water samples on time in the laboratory, the only alternative to perform a bacteriological analysis is with field testing kits (e.g. membrane filtration or the Most Probable Number methodology; see the respective user's manuals).
- In case water treatment is performed with chemicals, field test kits are essential to do a regular follow up of the treated water (iron / aluminium and/or chlorine residual measurements).

T.B. 2.12 Water treatment methods

The objective of treatment methods is to obtain potable water; meaning being “free” of microbiological contamination, having a low concentration of toxic chemical products and a low turbidity. Although they have a smaller direct health impact, factors as salinity, colour, odour and taste should not be neglected because they play an important role in the acceptability of the consumers.

Water treatment methods

To remove microbiological contamination:

The main objective of water treatment in precarious situations is the elimination of pathogens. The treatment methods to obtain this objective are:

Physical disinfection

■ Heating can destroy the pathogens. **Boiling** water is an effective way to disinfect small quantities of water (even when turbid) if it is performed correctly, but it doesn't protect against any further contamination (no remnant effect). To be completely sure that all pathogenic organisms are destroyed, the water should be brought to a rolling boil for at least one minute (although there is a lot of discussion on the minimum time needed), augmented by one minute for each altitude increase of 1000 m. This treatment method consumes a lot of energy and influences the taste of the water (which can be remedied by re-oxidizing the water by means of stirring or pouring it into another clean recipient).

■ **UV light** has the capacity of eliminating most pathogens, but it does not give a remnant protective effect to the treated water. However, UV irradiation can be a very interesting treatment method against pathogens which aren't affected by chlorine at normal drinking water concentrations; e.g. Hepatitis E virus. Another interest for UV irradiation (on big scale treatment) is when adding chlorine gives a significant colour variation of the treated water.

Special UV- C lamps have been developed to disinfect big quantities of non-turbid water in very short times, but they are rather fragile. After their foreseen lifespan (information provided by the manufacturer), they should be replaced, even when they still seem to function. The reason is that their irradiation frequency has shifted too far away from the ideal bactericidal wavelength (254 nm).

For small quantities of non-turbid water (< 20 - 30 NTU; T.B. 2.13), the principle of UV irradiation can also be achieved by the sun. Water stored in smooth, scratch free and transparent plastic (PET) 1 - 1.5 l bottles will be disinfected, but it requires long periods of full sunlight to be effective. This can be improved by painting one side of the bottle black or by placing it on a black corrugated iron sheet in order to increase the temperature of the water as well. The exposure time to full sunlight still needs to be 6 - 8 hours.

■ Certain **filtration procedures** are able to eliminate pathogens from raw water. Surface filters will remove all particles, including the pathogens that are bigger than their pore size, whereas smaller particles will remain in the water. These filters include ceramic candle and membrane filters. To avoid clogging, a frequent cleaning or replacement of the filters will be required. Slow sand filtration on the other hand uses a mechanical filtration combined with a natural biological membrane of micro-organisms that feed on organic matter, including pathogens. They are capable of removing susceptible particles as well, but if the turbidity is higher than 30 NTU, rapid clogging of the filters will occur (T.B. 2.17). A pre-treatment like roughing filters is thus required in order to have a cleaning frequency of once every two months. None of the filters give a remnant protective effect.

Chemical disinfection

■ Several chemicals such as chlorine, ozone and iodine can disinfect water. All products have their advantages and inconveniences, but most of the aid-agencies will disinfect water with **chlorine** (T.B. 2.19 to 2.23). The disinfection procedure with chlorine is rather easy to perform, relatively cheap and efficient against most bacteria and viruses. Another big advantage of chlorine is that it gives a remnant protective effect. It means that if a correct chlorine concentration has been added, a small accidental contamination of the treated water will be eliminated. However, at the concentrations used for drinking water, chlorine will not harm the protozoan cysts (Giardia or Cryptosporidium) nor the helminth eggs, which cause still a health hazard.

Chlorine won't be effective either if the water is turbid. Therefore it is important to measure the turbidity and if needed to remove it before the water is chlorinated. Disinfecting drinking water with chlorine, alone or in combination with pre-treatments, should systematically be done, certainly in emergencies and health structures.

To remove chemical pollution:

Because of the existence of huge amounts of different chemical substances, it is difficult to determine if the water is polluted and even more so by what substance (although a lot of different chemical analysis kits are existing; for more information, contact your technical referent). Additionally, the removal of chemicals is often difficult and expensive. Most of the water treatment methods available on the field are only capable of removing few chemical substances, but which can have their influence on taste, odour and colour. Hence, it is recommended to change water sources as soon as possible if there is a suspicion of chemical pollution.

To remove turbidity:

Turbidity is a measure indicating the amount of suspended particles in the water (T.B. 2.13). As such, it will directly affect the acceptance of the water by the consumers. Most disinfection methodologies are only really effective when no or a little amount of particles are present in the water. When measured (with a turbidity tube), the value should be less than 5 (N)TU, and certainly less than 20 (N)TU (for acute emergencies). If the turbidity exceeds these recommended values, a pre-treatment such as sedimentation (natural or assisted) and/or filtration should be done before disinfection can be initiated.

Sedimentation processes

■ **Natural sedimentation** is a process where the raw water is stored in a recipient over a certain period for the particles in suspension to fall down by gravity. The longer the period, the more particles will settle at the bottom of the water recipient, although this can take a very long time. These falling particles will also trap some pathogens and carry them to the bottom of the recipient where they will die over time. The long waiting times (several hours up to several weeks) make that this procedure is not very practical, and even unfeasible for emergencies. Water stored for longer periods also has to be protected from the sun to avoid algae growth, from breeding mosquitoes, from dust and other contaminants entering the recipient.

■ To speed up the sedimentation process, biological or chemical products (e.g. aluminium sulphate, ferric chloride) can be added to the water (T.B. 2.14 to 2.16). These products, the so-called coagulants, help the very small particles in suspension to aggregate into bigger and heavier flocks (higher density), so that they fall faster to the bottom of the recipient. As the process is assisted by adding coagulants, it is called **assisted sedimentation**.

Assisted sedimentation reduces the turbidity drastically, but to get under 5 NTU (the appropriate value for an effective chlorination) requires a waiting time that is often still too long for emergencies. The addition of flocculants or the use of polymers can reduce the sedimentation time (T.B. 2.14).

The residual concentration of chemical coagulants after assisted sedimentation without filtration are often too high according to the WHO directives. These residuals may have a negative impact on public health or on the acceptability of the drinking water by the beneficiaries. Assisted sedimentation does not completely remove pathogens like protozoan cysts and helminth eggs either. For all these reasons, water should preferably also be filtered before disinfection, certainly if a very low turbidity is required (e.g. for health structures).

Filtration processes

■ Filtration processes (T.B. 2.17) use a porous environment to separate the solids from the water. The porous environment lets the liquid pass while the solids are stopped. As described above, the **surface filters** and **slow sand filters** can reduce the turbidity, but they will clog (rather) rapidly. As the clogging isn't such a big problem for **rapid sand filters**, they are often considered as the preferred choice for filtration in emergencies. This filtration method can either be the next step following assisted sedimentation, or it can be direct but assisted with a coagulant (coagulated / flocculated water directly filtered on the sand) and then followed by chlorination.

Remarks

- Sources that are completely protected (e.g. protected wells or boreholes equipped with a good hand pump) and providing safe water can be exempted from treatment. However, when these sources are equipped with a motorised pump and a centralised storage system (e.g. health centres), it is recommended to chlorinate their water anyway to obtain the remnant effect.
- Only non-turbid raw water can be considered for simple chlorination, although that protozoan cysts and helminth eggs often survive this disinfection method and still cause health hazards. Thus different treatment methods will have to be combined in certain situations, certainly when the raw water is turbid. Some different scenarios as examples:
 - Acute emergency: turbidity < 20 NTU => simple chlorination (still risk of cysts / eggs).
 - Acute and chronic emergency: turbidity > 20 NTU:
 - assisted sedimentation + chlorination (still risk of cysts / helminth eggs).
 - assisted direct rapid sand filtration + chlorination (good quality water, limited to 300 NTU).
 - assisted sedimentation + rapid sand filtration + chlorination (good quality water).
 - Stabilized situation: preferably water sources not needing any treatment (except chlorination).

Properties of different treatment processes regarding the removal of several “contaminants”.

	Natural sedimentation	Assisted sedimentation	Ceramic candles	Membrane ultra / nano filtration	Slow sand filtration	Rapid sand filtration (assisted with coagulant)	Chlorination (with normal concentrations used for potable water)
Turbidity	1 (long waiting time)	3 (rather long waiting time to reach very low turbidity)	3 (rapid clogging, frequent cleaning)	3 (rapid clogging, frequent backwashing)	2 (max 30 NTU, need for roughing filters)	3 (up to 300 NTU)	0
Bacteria (+/-0.1-20 µm*)	1 (long waiting time)	1	3	3	2 to 3	0 (1 if assisted with a coagulant)	3
Viruses (+/-0.01-0.25 µm)	0 to 1 (long waiting time)	1	2	3	1 to 2	0 (1 if assisted with a coagulant)	2 (some viruses will survive)
Protozoa & Helminth eggs (+/-1-100 µm)	0 to 1 (long waiting time)	1	3	3	3	3	1
Salt	0	0	0	1	0	0	0
Colour, odour and taste	1	1	1	2	2	2	1
Remarks	- not often used due to its low efficiency	- turbidity reduction in emergency. -post rapid sand filtration desirable -post-chlorination compulsory	-small production -staff houses -small health structures -domestic treatment	-rather fragile -expensive -post-chlorination recommended	-slow production -small health structures -post-chlorination recommended	-camps -health structures -post-chlorination compulsory	-camps always -recommended in health structures -domestic treatment -remnant effect

In grey: the treatment procedures most commonly used by aid-agencies, often in combination with other methods

0: no impact, 1: low impact, 2: medium impact, 3: high impact - * µm = micron = 10⁻⁶ m

T.B. 2.13 Turbidity measurement

Turbidity is an important characteristic of water. It is an expression of the optical property that causes light to be scattered and absorbed by suspended particles and molecules, rather than being transmitted in straight lines through a water sample. The particles in suspension that interfere with the clarity of the water may include clay, silt, finely divided inorganic and organic matter, soluble coloured organic compounds, plankton and other microscopic organisms. Turbidity plays a major role in the chlorination efficacy. The objective of measuring the turbidity of water is to determine if there is a need for a pre-treatment such as natural or assisted sedimentation, and/or filtration.

Principles

The simplest and cheapest method to measure the turbidity is to use a turbidity tube, but it is unfortunately also a subjective measurement. A turbidity tube is often available in aid-agencies' chlorination kits and in some bacteriological analysis kits. The turbidity tube is a long and narrow graduated tube, in transparent plastic with a black ring or cross printed on the bottom. The measurements with a turbidity tube are expressed in (Jackson) Turbidity Units, or (J)TU.

To measure the turbidity in a more objective manner, electronic instruments are required. Several electronic measurement principles are existing, each with their own precision and price tag. The most precise electronic turbidity meters measure under 90° the remaining intensity of the light that has been emitted by a specific lamp through a water sample, potentially compared to a light intensity measurement at 180°. With this principle, the measured values are expressed in Nephelometric Turbidity Units (NTU), which is also the most commonly used unit.

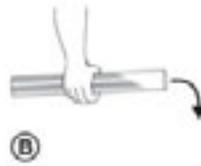
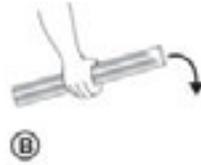
Because extreme high precision is mostly not needed on the field and due to the price, most turbidity measurements will be done with the tube. Note that some turbidity tubes have wrongfully a NTU scale, but as it's a similar scale to JTU, it doesn't really matter. Anyway, other turbidity units than JTU and NTU exist (depending on the electronic measurement system), all with a similar scale.

Operation

- Rinse the turbidity tube 3 times abundantly with the water to be tested.
- Fill the turbidity tube completely (until the 5 TU mark) with the water to be tested.
- Wait a few seconds for the water to stabilize and the air bubbles to disappear.
- Try to detect via the opening and through the mass of water the black ring or cross at the bottom of the tube. This has to be done with the tube in vertical position.
- Remove gradually water from the tube (if necessary) until the black mark on the bottom can be detected.
- Read the result by comparing the water level in the tube and the graduation present on the tube wall. This has to be done with the tube in vertical position.
- Empty the tube and rinse it three times with clean water if it's available.

Remarks

- Never chlorinate turbid water because the particles in suspension can protect micro-organisms from the disinfectant action. Water to be chlorinated must have a turbidity lower than 5 (N)TU, but in acute emergencies, a turbidity up to 20 (N)TU is permitted. If the turbidity exceeds the recommended values, a pre-treatment such as sedimentation (natural or assisted; T.B. 2.14 and 2.16) and/or filtration (T.B. 2.17) should be done before the chlorination procedure can start.
- The reading of a turbidity tube must be done in good illumination conditions (natural day light), but avoid sunlight shining directly on the turbidity tube as this might falsify the readings. Use your own shadow in a non-shaded area. Sun glasses must also be taken off during the measurement.
- Some turbidity tubes are proposed in several sections that have to be fitted into each other. In this case, take care to hold the turbidity tube by its lower section to avoid that it would fall and break during the filling up process or during the reading.



Key

Input

- A. Black ring (or cross) detection
- B. Gradual removal of water from the tube
- C. Reading of the result

- 1. Turbidity tube (not to scale)
- 2. Black ring or cross on the bottom of the tube
- 3. Graduation

- Turbidity tube

T.B. 2.14 Coagulants / flocculants

When the turbidity of the (raw) water is high, chlorination isn't effective. The recommended turbidity value for effective chlorination is set at 5 (N)TU, although turbidities up to 20 (N)TU are still acceptable during the acute phase of an emergency. If these values are exceeded, the turbidity of the (raw) water has to be reduced. If the particles responsible for the turbidity are rather big and heavy (high density), they will settle down in a natural way when the water is standing still. If they don't settle naturally, a chemical or a biological product called a coagulant can be added to assist the sedimentation process or the direct rapid sand filtration. Flocculants can be added separately or are integrated in a combined coagulation / flocculation product to speed up the process.

Principles

Coagulation / flocculation

Coagulants have the potential to neutralise the electrical repulsion phenomena that keep the particles in suspension within the raw water. Once the right amount of coagulant (often under the form of a solution) has been added and well mixed with the water to be treated, the neutralised particles can join each other and start to grow into flocks (flocculation). Some additional products, so-called flocculants (sometimes a combined product) can be added to speed up the flocculation process. In order to determine the right dose of the coagulant / (flocculants) to be added, a jar test has to be performed on the raw water (T.B. 2.15).

Assisted sedimentation

As these flocks have become bigger and heavier (higher density) than the original particles (due to the coagulation / flocculation processes), they will start to settle down within the water recipient / reservoir. This will improve the turbidity of the treated water drastically (T.B. 2.16).

Direct Rapid Sand Filtration

It is also possible to retain the formed flocks directly from the water by means of a rapid sand filter, without having to pass the sedimentation process (T.B. 2.17). Direct Rapid Sand Filtration will improve the quality of the treated water even more in comparison with assisted sedimentation, but is limited for very high turbidities (the filtration periods become very short if the turbidity of the raw water exceeds 300 NTU).

Assisted sedimentation combined with Rapid Sand Filtration

A combination of assisted sedimentation with rapid sand filtration is possible as well when water with an extremely high turbidity needs to be treated and high quality water is required.

Commonly used products in relief work

- Aluminium sulphate, $Al_2(SO_4)_3$ is the best-known coagulant worldwide and it can be found in most (low-income) countries (e.g. often stored in water treatment plants).
- Ferric chloride, $FeCl_3$ is less known, but does have several advantages over aluminium sulphate.
- Polymers are very effective coagulants / (flocculants). These products become available as well under powder and tablet form, which makes their transport easier in comparison with the liquid polymers.
- Some biological products such as grinded *Moringa oleifera* tree seeds exist as well. They are not commonly used for big scale treatment, but rather at domestic level.

The following table gives a comparison of different chemical coagulants, often used by aid-agencies:

Product	Advantages	Disadvantages
Aluminium sulphate	<ul style="list-style-type: none"> • crystallised (sometimes lumps) • often available on the field • not expensive • no expiry date • often known by national counterparts 	<ul style="list-style-type: none"> • available only at low concentration (w/w*: 17 - 18%) • mainly usable within a pH-range of 6.0 to 7.4 (T.B. 2.10) • rather difficult to dissolve
Ferric chloride	<ul style="list-style-type: none"> • crystallised (but also available as a liquid) • high concentration (w/w*: 60%) • usable in a wide pH-range of 5.0 to 9.0 (T.B. 2.10) • not expensive at purchase • no expiry date (stable, even dissolved) • easy to dissolve • no (IATA) air transport regulation 	<ul style="list-style-type: none"> • rarely available on the field • importation needed • water might turn yellowish • corrosive • granules absorb very quickly humidity, becoming a wet paste or a solid block when dried out again (resulting in difficulties to prepare a mother solution)
Polymers	<ul style="list-style-type: none"> • extremely good coagulants / flocculants • usable in a very wide pH-range of 4.0 to 9.0 (T.B. 2.10) • normally little amounts needed <p>* w/w: weight for weight</p>	<ul style="list-style-type: none"> • often low concentration available • dosage can be difficult • rarely available on the field • importation needed • not stable during long period • possible (IATA) air transport regulation • possibly expensive

Preparation of the mother solution

- Polymers are often used under their pure form because their coagulation / flocculation procedure starts already with the elements of the water that is used to make the mother solution.
- Ferric chloride and aluminium sulphate must be used under a liquid form, mostly a 1% mother solution, although other concentrations might sometimes be required as well. The preparation is similar as for chlorine solutions (T.B. 2.20):

$$X = Y \times N \times (100/C)$$

With

- X = grams of product to be added per litre of water to reach the desired solution concentration (g/l)
- Y = desired solution concentration (%)
- N = 10 g/l: equal to the amount of coagulant needed to make 1 litre of 1% mother solution if its concentration would be 100%
- (calculation: 1 l of water weighs 1000 g ; 1% of 1000 g = 10 g and 1% solution = 10 g/l)
- C = concentration of the coagulant's concentration (w/w); as mentioned on the packaging (%)

Examples:

Make 1 litre of 1% mother solution with FeCl_3 , concentrated at 60% w/w

$$\rightarrow X = 1 \times 10 \times (100/60) = 16.7 \text{ g/l (about 17 g/l)}$$

Make 1 litre of 1% mother solution with $\text{Al}_2(\text{SO}_4)_3$, concentrated at 18% w/w

$$\rightarrow X = 1 \times 10 \times 100/18 = 55.6 \text{ g/l (about 56 g/l)}$$

Make 1 litre of 2% solution with $\text{Al}_2(\text{SO}_4)_3$, concentrated at 18% w/w

$$\rightarrow X = 2 \times 10 \times 100/18 = 111.1 \text{ g/l (about 111 g/l)}$$

Remarks

- Based on effectiveness, polymers are by far the best coagulant / (flocculants) for assisted sedimentation. These products are mostly so effective that only very little amounts of them need to be used. They are effective in a wide pH variety of the raw water, and they form big flocks that can settle down rapidly. Due to the formation of big flocks, these products are less suited for direct rapid sand filtration because they might clog up the filtration medium.
- As it is often difficult to make a mother solution with polymers, they have to be mixed directly with the raw water under their pure form. This can render the fine tuning of the assisted sedimentation process quite difficult and a jar test nearly impossible. An insulin syringe (1 ml) could be used to attempt a jar test with 1 litre beakers, as only a few drops of pure liquid polymer are needed. As such, the jar test will stay an approximation, but still precise enough to start the emergency water treatment.
- An alternative for unknown raw water (characteristics) is ferric chloride as it is also usable in a rather wide pH range. This product can be used as well for assisted sedimentation as for direct rapid sand filtration. With relatively short assisted sedimentation times in emergency treatment and/or when the dosage is incorrect (this for both the assisted sedimentation and the filtration procedures), the water treated with FeCl_3 might turn (a little) yellowish. Although iron isn't harmful for people's health, the beneficiaries might reject the treated water due to its colour and certainly when high residual concentrations render it unpalatable. Anyway, it is recommended that the iron (residual) concentration stays within the approved long-term standards, namely 0.2 mg/l.
- Aluminium sulphate is interesting for assisted sedimentation and direct rapid sand filtration, certainly as it can be found nearly everywhere in the world for reasonable prices. Ideally, the pH of the raw water should be between 6.0 and 7.4, because beyond this pH range, the needed amounts of the product rise drastically. It is recommended to buy aluminium sulphate directly under crystallized form because the breaking of lumps into crystals to ease the preparation of the mother solution requires a lot of work and protective clothing (e.g. gloves, mask, goggles).
- There are some unconfirmed studies claiming that "high" aluminium concentrations (within drinking water) might in the long run cause Alzheimer disease and neurological disorders. Potentially more worrying for (emergency) aid-agencies is the unconfirmed concern that malnourished children consuming water with high concentrations of (residual) aluminium might not pick up their weight again. Although that there are still a lot of discussions on the potential adverse health effects of this product, it is important to measure its residual concentration with an appropriate test kit after the water has been treated with a coagulant containing aluminium. The residual aluminium concentration should always be kept as low as possible (ideally less than 0.2 mg/l). In case any of the measurements are outside the normally used standards (indicators), advice should be sought from your technical referent.
- Strict quality control measures need to be respected when purchasing chemicals for potable water treatment (e.g. coagulants, disinfectants). In case of local purchase, contact your technical referent in order to assure that they are fit for human consumption.
- Even though ferric chloride and aluminium sulphate don't have an expiry date, they should always be stored under correct conditions, meaning a cool dark place with low humidity.
- Several products combining a coagulant, potentially some flocculants, and a disinfectant are available under the form of tablets or sachets. These products are intended for individual household or small scale community water treatment. A certain vigilance is required with these products because fixed doses of different chemicals are added to a determined amount of raw water that can have any quality, without performing a jar test (T.B. 2.15) or a Modified Horrocks test (T.B. 2.21). The Free Residual Chlorine concentration (T.B. 2.22) of the treated water should at least be analysed, and preferably also its residual aluminium or iron concentration (depending on the coagulant used in the product). In case any of the measured values are outside the normally used standards (indicators), advice should be sought from your technical referent. Besides the potential technical issues, a lot of attention should also go to the distribution procedure of these products. It is also important to verify if the beneficiaries use the product properly. Hence, a promotion and training campaign will be of utmost importance.

T.B. 2.15 Jar test for coagulants

A jar test determines the quantity of a coagulant (mother) solution that is required to treat a certain volume of turbid water. If the added coagulant dose is too low or way too high, no coagulation / flocculation will occur. A small overdose will work, but it represents a spillage of resources and an increased residual concentration.

Operation

Pre-tests

- Measure the pH and the turbidity of the raw water. These analyses can be done with the pool tester (T.B. 2.22) and the turbidity tube (T.B. 2.13).
- Perform additional analyses on the water's conductivity and alkalinity (pH buffer effect), certainly when the jar test isn't successful over a wide range of coagulant dosages.

Jar test for aluminium sulphate / ferric chloride solutions

- Prepare a 1% mother solution of the coagulant (T.B. 2.14).
- Place at least 5 one litre transparent measuring beakers (jars) on a flat working space. The advantage of transparent recipients is that the flocks will easily be detectable.
- Rinse all the beakers three times with the raw water to be treated.
- Fill the rinsed beakers to their 1 litre mark with the raw water to be treated.
- Inject with a syringe (e.g. 10 ml capacity) a dose of 1% coagulant solution in every beaker, by increasing gradually the amount (e.g. 0.5, 1, 3, 5 and 7 ml). Mark the injected doses on the beakers to avoid confusion afterwards.
- Stir the coagulant thoroughly in a circular movement during about a minute, immediately after the dose has been injected. The stirring can be done with the syringe itself.
- Detect if flocks start to appear in one or more recipients after some time. This process should normally appear before the water stops turning in the beaker. If this is not the case, there is only a small chance that flocks will still form.
 - When no flocks have formed in any of the beakers before the water stopped turning, the jar test will have to be repeated completely with higher dosages, although there might be other reasons for the raw water not to flocculate (e.g. unfavourable conductivity and/or pH buffer effect).
 - When flocks have formed in the beaker with high dosage but not in the jars with lower dosages, the highest dose (e.g. 7 ml) can be added to each of the latter jars (e.g. going to 7.5, 8, 10, and 12 ml).
 - When no flocks have formed for the high dosages only, the "ideal" dose might be passed already.
- Wait about 30 minutes after the end of the mixing process for the flocks to settle down.
- Compare visually the results in the different beakers (turbidity, size of the flocks, velocity of settling down). The jar with the best results indicates how much coagulant should be added per given amount of raw water. If there is hesitation in between two recipients, the "ideal" dose might probably be in between both of them.
- Fine-tune the dosing around the most favourable values by repeating the jar test completely in the same way as described above. For instance, if the beakers in which 3 and 5 ml of coagulant were injected gave the best preliminary results, the jar test can be repeated with dosages in between these values (3 ml, 3.5 ml, 4 ml, 4.5 ml and 5 ml).
- Wait about 30 minutes after the end of the mixing process for the flocks to settle down.
- Compare visually the results in the different beakers (turbidity, size of the flocks, velocity of settling down). It can be tried to pour the supernatant gently in a turbidity tube, without having flocks coming along or breaking up. If it is still difficult to determine the best result because the turbidity of several jars is the same, choose the one where the least coagulant solution was injected. Note that the (field) jar test is only an indicator of how much coagulant solution needs to be added in reality.
- Extrapolate how much coagulant is required for the production of a big amount of water (e.g. 30 m³), based on the "ideal" dose that has been determined by the jar test.

Example for aluminium sulphate:

Jar test indicates 3 ml of 1% $Al_2(SO_4)_3$ solution per litre of raw water, extrapolated for a 30,000 l tank
→ 3 ml/l x 30,000 l = 90,000 ml/tank = 90 l of 1% mother solution per batch of 30,000 l.

Based on the active ingredient of $Al_2(SO_4)_3$, 5 kg will be needed for the 90 l (55.6 g/l x 90l; T.B. 2.14).



Key

1. Recipients (1l) with raw water
2. Syringe with coagulant solution

Input

- 1 l transparent beakers (or similar: glasses, glass jars, plastic buckets)
- Syringe (10 ml)
- Coagulant (solution)
- Watch
- Turbidity tube
- Pool tester
- (Conductivity meter)
- (Alkalinity test)

Polymers

- As it is often impossible to make mother solutions with polymers (they might start to flocculate already with the water of the solution), these coagulants have to be used under their pure form. This means that the realisation and interpretation of a jar test are extremely difficult due to the very low volumes of these products required to treat turbid water (in the order of 0.01 to 0.15 ml/l of raw water). An insulin syringe (1 ml) could be used to attempt a jar test with 1 litre beakers. As such, the jar test will stay an approximation, but precise enough to start the emergency water treatment.
- Therefore is the jar test for polymers often skipped in emergency situations. Hence, the tests are immediately done in situ, on large scale. Anyway, polymers are mostly less critical in their dosing in comparison with coagulants like aluminium sulphate or ferric chloride. Nevertheless, regular residual aluminium / iron concentration analyses should be done on the treated water.
- In practice, foresee about 0.5 to 3 l of liquid polymers per reservoir of 30 m³. Be aware that these values are only an indication in which range large scale tests should be made.

Post-tests

- Measure the pH and the turbidity of the treated water by means of the pool tester (T.B. 2.22) and the turbidity tube (T.B. 2.13). These tests are actually the pre-tests for chlorination (Modified Horrocks test) (T.B. 2.21 and 2.22).
- Analyse the residual metal concentration, depending on the coagulant being used (iron or aluminium). Their concentration should normally be lower than 0.2 mg/l. Be aware that the concentrations after a field jar test and emergency assisted sedimentation are often up to 10 times higher.

Remarks

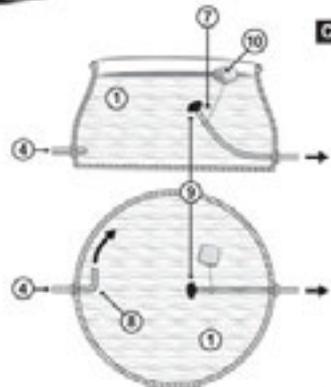
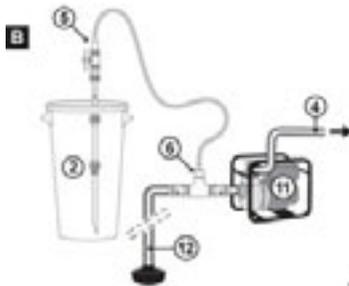
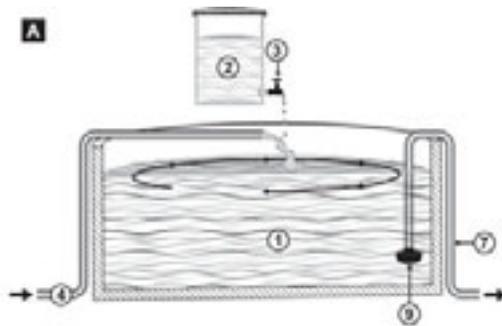
- If transparent beakers aren't available, big glasses (e.g. pints), glass jars or even plastic buckets with all the same and known volume can be used as well. During the jar test, the injected doses of coagulant will have to be adapted according to the volume of the recipients.
- The thorough stirring immediately after the coagulant has been injected in the raw water is important to have a homogeneous mixture. This avoids over- and under-dosing at different places in the recipient, and enhances the formation of flocks. Under laboratory conditions, once the thorough stirring is done, a slow mixing at specific speeds will continue by an electric apparatus for 20 minutes. As this is very difficult to achieve manually on the field, the slow mixing is limited until the swirl after the thorough stirring stops. This isn't ideal, but it still gives a good indication of the required coagulant dosage.
- When the alkalinity (pH buffer effect) of the raw water is low, its pH can drop significantly when coagulants are added, as most of them are acid. This can have a serious influence on the quantity of coagulant needed, certainly when aluminium sulphate is used. A low pH buffer effect could even hamper the coagulation / flocculation process. The pH of the raw water can be adapted (made higher or lower) with certain products (e.g. respectively lime or sulphuric acid), but due to its specific difficulties (e.g. dosing, safety), advice from your technical referent should be sought.
- A very low concentration of ions (low conductivity) in the raw water can cause problems as well with the coagulation / flocculation process. Rendering the conductivity a little higher by adding some kitchen salt might solve the problem, but it is recommended to contact your technical referent for further information.
- The presence of high quantities of algae or other organic material that can be found in swamps for example, might require the use of a lot more coagulant.

T.B. 2.16 Assisted batch sedimentation

Natural sedimentation might take a very long time, which can drastically be reduced by adding a coagulant (and flocculants) to the raw water. This process is called assisted sedimentation. Coagulants (and flocculants) will enhance the aggregation of the very small particles in suspension in order to make them bigger and heavier (higher density). They will then settle down faster, thus lowering the turbidity of the water within a more reasonable time span.

Operation

- Install the sedimentation reservoir preferably at a spot nearby the raw water source, but far enough to avoid that it gets flooded when the water level would (suddenly) rise. Make sure that the reservoir is installed on a solid and horizontal “platform” for security reasons.
- In emergency situations, onion tanks or big (circular) tanks with a metallic frame and plastic lining are the easiest and fastest to install (T.B. 2.35; 2.36). These reservoirs should have a useful height of at least 1 m.
- Reservoirs with metal sheeting as a support can be used as well, but it takes longer to install them (T.B. 2.35).
- Install a motor pump with its needed accessories (e.g. strainer, suction and delivery pipes; T.B. 2.28).
- Add the coagulant (solution) in proportional quantities (as determined by the jar test; T.B. 2.15) during the time the tank is filled with raw water. The coagulant can be added to the raw water in various ways:
 - Simple drop-drop system (for all kinds of coagulant solutions / liquid polymers):
 - The principle of this system is that the coagulant gets mixed by simply being dropped into the raw water spouting out of the pump’s delivery pipe (as per figure A). The advantage is that only a plastic recipient with a tap to regulate the coagulants flow is required. The recipient should be installed on some kind of platform, together with the delivery pipe. The delivery pipe should be oriented tangential to the reservoir in order to create an internal circular movement of the coagulated water, which will improve the flocculation process. However, the water falling into the reservoir might break the flocks already forming in the rotating water (certainly when the reservoir is still rather empty).
 - When liquid polymers are used as coagulant, a 20 l jerrycan with tap can be sufficient as recipient. Its dosing can be fine-tuned to some extent by adding an infusion set, if available.
 - Rather big quantities of aluminium sulphate or ferric chloride solutions will be required, thus a bigger recipient (e.g. 120 l jar for cholera interventions) or several jerrycans will be needed.
 - Suction Side Dosing (SSD) system (only for coagulant solutions, not for liquid polymers):
 - This device, equipped with a regulation valve and a small flow meter, is installed at the entrance of the pump (as per figure B), so the coagulant solution can be “sucked” up proportionally to the raw water flow. The “flash” mixing of both liquids by the impellor of the pump enhances the coagulation process. The 90° elbow (as per figure C) allows the coagulated water to arrive in a circular movement at the bottom of the reservoir, which will improve the flocculation process, and without breaking the already existing flocks. All these factors result in an enhanced reduction of the turbidity.
 - The flow of coagulant solution that needs to be injected is determined by the jar test; e.g. the jar test indicates a need of 4 ml of coagulant solution per litre of raw water:
 - The pumping rate of the raw water is 25,000 l/h.
 - The injection rate of the coagulant solution is: $4 \text{ ml/l} \times 25,000 \text{ l/h} = 100,000 \text{ ml/h} = 100 \text{ l/h}$.
 - Turn the regulation valve of the SSD system in such a position that its flow is set at 100 l/h (indicated by the SSD flow meter).
- Allow the flocks to settle down at the bottom of the tank, once the reservoir is completely filled. This might take several hours.
- Retrieve the clarified water with great care. Settled flocks can be pumped up when the flow rate is too high or when the entrance of the retrieval pipe comes too close to the sludge at the bottom of the reservoir. Sometimes, the flocks might float on the water surface. In this case, the clarified water has to be retrieved from underneath them. To deal with these problems, a retrieval pipe with floater can be connected to an outlet at the inside of the reservoir (as per figure C). This also allows the removal of the treated water by gravity in a safe way. This principle is strongly recommended if an onion tank is used for sedimentation.



Key

Input

- A. Drop-drop system and retrieval from open rigid reservoir
 B. Suction Side Dosing (SSD) system
 C. Water delivery to (for SSD system) and retrieval from open reservoir

- | | |
|--|---|
| <ol style="list-style-type: none"> 1. Reservoir filling with water 2. Coagulants recipient 3. Valve / tap of the coagulant's recipient 4. Delivery pipe 5. Suction Side Dosing (regulation valve / flow meter) 6. Connection Suction Side Dosing system to pump 7. Retrieval pipe for the treated water 8. 90° elbow 9. Strainer on retrieval pipe 10. Floater 11. Motor pump 12. Suction hose with strainer | <ul style="list-style-type: none"> - Reservoir (pool or onion type) - Plastic 20 l jerrycans or 120 l jar - Construction materials / tools for the platform - Suction Side Dosing system - Pipes, T-pieces and valves - Coagulant (solution) - Motorised surface pump and accessories (kit) - Floater - Sticks and some rope to prepare the cross that avoids that the floating retrieval pipe descends too deep |
|--|---|

Remarks

- Assisted batch sedimentation is an appropriate treatment method in the first phase of an emergency or as pre-treatment before filtering, because it requires a limited amount of material. However, depending on the settling time of the flocks, several reservoirs in parallel might be needed to come to the required water production rate.
- Bladder tanks should not be used for (assisted) sedimentation because their shape doesn't allow a circular movement of the coagulated water and it would be difficult to retrieve the treated water without having flocks coming along. Because they are completely closed, it would also be difficult to remove the sediments afterwards.
- Besides the described batch procedure, the assisted sedimentation can also be done continuously by inclined plate sedimentation or up-flow clarification for instance.
- Polymers have better performances for assisted sedimentation in comparison with the other coagulants used on the field. But as they are used undiluted (related to the difficulties to make a mother solution), polymers are more difficult to dose. Coagulants such as aluminium sulphate and ferric chloride are introduced in the raw water as a diluted solution (mostly 1% mother solution), thus their dosing is less difficult (T.B. 2.14).
- A further treatment method, at least a disinfection of the water, must follow the assisted sedimentation process. Be aware that assisted sedimentation will not eliminate all cysts nor all helminths eggs, neither will chlorine. Hence, it is also recommended to filter the water before chlorination, certainly where very good quality water is required (e.g. health structures).
- With the rather short sedimentation times available during emergencies, the treated water often has high residual concentrations of metal coagulants (the standard is 0.2 mg/l, but in reality it is often up to 10 times higher). Field test kits for measuring the aluminium / iron residual concentration should be available to do a regular follow up of the treated water.
- These high residual metal concentrations due to the coagulants might have a negative impact on the health of vulnerable people (e.g. severely malnourished children) or on the consumers' acceptability of the water (colour, taste). These residual metal concentrations can be reduced by (rapid sand) filtration.
- The sludge doesn't have to be removed after every cycle as it helps to form flocks during the next batch (certainly if the turbidity of the raw water is rather low). However, as the sludge layer thickens, the water production per cycle reduces. Therefore it is necessary to clean the reservoir at regular intervals. This can be done manually by putting the flocks in suspension (e.g. with soft brooms) during the draining of the reservoir or by means of a motor or even better a dewatering pump (T.B. 2.25).
- To preserve the environment, a sedimentation hole should be dug for the drained water to pass through. If the retention time in the hole is long enough, the flocks can settle down. Initially, it's possible that the drained water will even infiltrate in the underground, but after a while the soil will certainly be saturated. The "overflowing" water should be drained back to the surface water, but down-flow of the intake of the raw water pump.
- The Suction Side Dosing system cannot be used for liquid polymers, because its regulation isn't fine enough for the undiluted product. There is also the risk that the aggressiveness of certain polymers would destroy the seal of the pump axle.
- Several products combining a coagulant, potentially some flocculants, and a disinfectant are available under the form of tablets or sachets. These products are intended for individual household or small scale community water treatment. A certain vigilance is required with these products because fixed doses of different chemicals are added to a determined amount of raw water that can have any quality, without performing a jar test (T.B. 2.15) or a Modified Horrocks test (T.B. 2.21). The Free Residual Chlorine concentration (T.B. 2.22) of the treated water should at least be analysed, and preferably also its residual aluminium or iron concentration (depending on the coagulant used in the product). In case any of the measured values are outside the normally used standards (indicators), advice should be sought from your technical referent. Besides the potential technical issues, a lot of attention should also go to the distribution procedure of these products. It is also important to verify if the beneficiaries use the product properly. Hence, a promotion and training campaign will be of utmost importance.

T.B. 2.17 Filtration methods

To obtain high quality potable water, filtration is often necessary. Filtration uses a porous environment to separate the solids from the water. The porous environment lets the liquid pass while the solids are stopped. Most of the systems used on the field function with a support / surface filtration or with a granular bed filtration. Examples of processes often used on the field are presented hereunder.

Support / surface filtration

All systems based on support / surface filtration function in a similar way: the water has to pass through a surface with very fine pores, which will retain the particles that are bigger than the pores. These filters are effective, but do clog rapidly when the turbidity of the water is high. Thus they need to be cleaned regularly, and some systems even need a frequent replacement of the filters. Typical examples of surface filtration are cartridge and membrane filters.

Cartridge (candle) filtration

The raw water passes through cartridges, made of metals, fibres or ceramic material, with a fine porosity. Particles in suspension, cysts, helminth (eggs), most bacteria and a certain range of viruses will be retained. Therefore, the treated water is of good quality. However, turbid water will clog the filters rather rapidly as the particles settle down on their surface (the higher the turbidity, the faster the clogging). Even with a low turbidity, the cartridges have to be cleaned frequently, certainly when they are pressurised.

Ceramic candles (T.B. 2.18) are most often used for individual and household water treatment, due to their low production rate. They are mainly found in survival kits, in expatriates' houses and sometimes in (small) health structures. Under certain circumstances however, they might also be the preferred choice for a population to do their own household water treatment. As the abrasive cleaning of the candles with a brush or a rough sponge has to be done rather often, they need to be replaced frequently (ideally every 6 months and at least once a year).

Membrane filtration

This filtration method consists of permeable membranes, often rolled up in tubes which are stored in cylindrical containers. The kind of filtration (**micro-, ultra- or nano-filtration**) is determined by the size of the membrane pores. As the pores are extremely fine, suspensible particles, cysts, helminth eggs and bacteria can be retained, even viruses when ultra- or nano-filtration membranes are used. However effective this kind of filtration is, post-chlorination is still strongly recommended to have a remnant protection effect. As these kinds of systems function on the surface filtration principle, they have a tendency to clog rather rapidly, certainly with a high turbidity. So (very) regular backwashes with clean water are necessary, but these are often managed automatically. Producing very high quality water without the need of chemicals (except for the recommended post-chlorination and some acids / alkalis for cleaning once in a while), these filtration systems are unfortunately also very expensive and the membranes are still rather fragile.

Reverse osmosis is also associated to the membrane technology. In this case, (extreme) high pressures are used to remove even dissolved elements like salt out of the water. These systems are not at all adapted for turbid water. Small scale **forward osmosis** filters for pathogen removal are also available. Their driving force to filter the water does not come from hydraulic pressure (pump, gravity), but from osmotic pressure.

Granular bed filtration

In this process, the suspensible material is stopped in the inter-granular spaces of the filtering material (often sand). In general, two treatment methods on a granular bed principle are commonly used: slow and rapid sand filtration. Slow sand filtration is a mechanical and microbiological process. Rapid sand filtration is only a mechanical process, which is also based on sieving but mainly on the principle of adsorption.

Slow Sand Filtration

The mechanical filtering action of the granular sand bed together with the biological membrane that will develop on top after some time (named Schmutzdecke) can remove cysts, helminth eggs, a large part of the bacteria and even some viruses from the water. It gives also good results in clarifying the raw water, as long as it doesn't contain too many particles in suspension. Slow sand filtration isn't suited to deal with turbidities above 30 NTU. In case the turbidity is above this level, the raw water should pass through roughing filters, which is actually a system of natural sedimentation. A post-chlorination of the water leaving the slow sand filters is always recommended to obtain a remnant effect.

However simple the process seems, there are some limits. As the velocity is low (0.1 - 0.3 m/h), the head losses stay low, so that the filtration can be done by gravity. On the other hand, big filters are required to obtain a sufficient water production for a large population (e.g. a surface of 20 m² will produce a flow of 2 to 6 m³/h). The system has to run 24 hours a day to guarantee the water quality. After maintenance work is done, it will take at least several days for the Schmutzdecke to reform itself, and the pathogens won't be removed over that period. To overcome this problem, two parallel slow sand filters need to be installed and maintained alternately. Another option is to build a big storage reservoir, which can only be filled if the daily production of the slow sand filter is (a lot) higher than the required daily demand.

As the production capacity is rather low, slow sand filtration isn't often used in emergencies. Contact your technical referent before taking the decision to implement such a filtration system.

Rapid sand filtration

A rapid sand filter operates on two principles; some mechanical straining and mainly physical adsorption on the surface of the sand grains. Rapid sand filtration can be installed after an assisted sedimentation process to remove the flocks (including the bacteria and viruses trapped inside), cysts and helminth eggs that would have escaped otherwise. The rapid sand filter will also be able to remove the coagulation residuals (e.g. iron or aluminium). This gives good quality water, but needs three different steps with the post-chlorination included.

Direct assisted rapid sand filtration is possible as well; a coagulant will be added and the flocks will be filtered out directly without sedimentation in a reservoir first. This process will remove the coagulants' residuals to acceptable concentrations (possibly even less than 0.2 mg/l, which is the maximum standard), reduce very efficiently the turbidity of the raw water (< 5 NTU) and retain most helminth eggs and cysts. However, the turbidity of the raw water should not exceed 300 NTU, because the filtration periods will become too short and backwashing will be needed too often. In such situations, it is recommended to add assisted sedimentation (in batch or continuous) prior to the filtration step.

According to the application, rapid sand filtration is done with velocities going from 4 up to 50 m/h, thus a (relatively) high water production is possible with small filters. Several filters with filtration beds of different granulometry can be put in series to obtain a better reduction of the turbidity over longer filtration periods. The backwashes of the filters are done with pre-filtered or completely treated water, but compressed air, as used in big water treatment plants, is often abandoned for small field treatment units because of the complexity and extra expenses.

As the contact time in between the water and the sand is short, it's impossible to have the biological action that appears in slow sand filtration. Thus the free bacteria and viruses that aren't trapped in the flocks won't be eliminated by rapid sand filtration, and post-chlorination becomes obligatory.

Direct rapid sand filtration is a frequently used principle for field water treatment kits. This is due to the production of potentially large quantities of high quality water (in combination with post-chlorination and possibly pre-sedimentation) for rather low purchase costs and low operation and maintenance expenses.

T.B. 2.18 Ceramic candle filters

Water is passed through micro-porous ceramic walls with a pore diameter of about 0.45 μm (depending on the quality of the filter), retaining all particles with a bigger size at the surface of the candle filter. Ceramic candle filters can therefore remove practically all suspended material from water, including protozoa, helminth eggs, most bacteria and some viruses. This technique is nevertheless not effective for dissolved substances like salts and chemical pollutants. Some types of ceramic candle filters contain silver salts that are bactericide and that will prevent the development of a bio-film inside the candles. According to the models, activated carbon can also be present inside the candles for adsorbing some dissolved substances, thus reducing the risk of possible taste, odour or colour of the water.

Principle

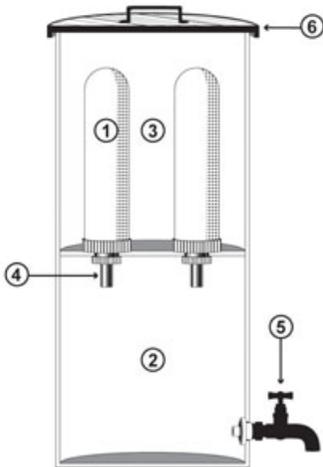
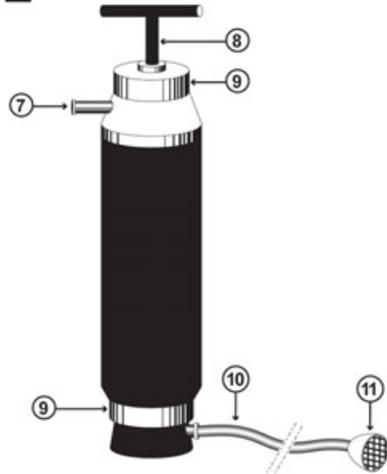
- Gravity filter: One recipient containing several candles stacks on the top of another, which is collecting the treated water. By filling the upper recipient, the water will pass drop-by-drop through the candles (provided they are not clogged) into the lower container. The filtered water can immediately be taken from the tap at the lower recipient.
- Pump filter: In this case, the water is forced under pressure through the filter by means of a small integrated hand pump, thus increasing the flow. The strainer of its plastic "suction" pipe should be put into the raw water before the pumping starts.

Operation and Maintenance

- Assemble the candles of the gravity filter correctly with their rubber washers placed in between the candle and the internal base of the upper container and their nuts properly tightened to ensure that no water can pass without being filtered.
- Keep the container where the filtered water is collected and preserved closed. It should be cleaned at least once a week with a 0.05% chlorine solution (T.B. 2.20) and rinsed afterwards with filtered water, without touching the inside of the container.
- Brush the candles under clean running water when their flow becomes too weak, rinse them and reassemble the filter (see manufacturer's instructions). A specific brush or rough sponge should be included in the kit, but in case this specific cleaning material isn't available, a semi-hard non-metallic brush specially dedicated for this use can be utilized as well. As the candles are fragile, handle them with care.
- Clean and air-dry the (pump) filters completely when they won't be used over prolonged periods (e.g. weeks to months). This avoids fungus and bacteria growth inside, which could lead to illness when the filter is put back into service.

Remarks

- Teams in the field should always drink filtered water because they can never be sure of the quality of local water supplies. Candle filters can also be useful in (small) health centres, certainly in the starting up phase. If proper promotion is done, these filters can also be considered as a household water treatment method for populations.
- It is recommended to purchase ceramic candle filters of renowned brands to be assured of good quality water afterwards.
- Always follow carefully the installation, operation and maintenance instructions included in the packaging.
- Never consume the filtered water immediately after the system has been set up, because it may contain ceramic particles and/or a high concentration of colloidal silver.
- Avoid contact between boiling water and the candles as there is a risk that (small) cracks will be formed in the ceramic material, undermining thus the filtration efficacy.
- While cleaning the candles, care should be taken that dirty water can't enter via their outlet. This would contaminate the inside of the filter, rendering it useless.
- In continuous utilisation, the candles should ideally be replaced every 6 months, and certainly after a year. As a consequence, it is important to mark, preferably on the filter, the installation date of the candles. Some manufacturers (certainly of pump filters) provide a measuring gauge allowing to verify the diameter of the candle; it should be changed as soon as the gauge can pass freely around it (see the manufacturer's instructions).

A**B****Key**

- A. Gravity filter
B. Pump filter

1. Ceramic candles
2. Container collecting filtered water
3. Container of water to be filtered
4. Candle fastening with rubber washer
5. Tap
6. Cover
7. Outlet for filtered water
8. Hand pump mechanism
9. Fastening collars
10. Flexible tube (for raw water)
11. Strainer (to pre-filter raw water)

InputGravity filter: containing

- 2 containers (metal or plastic)
- lid
- ceramic candles (2 to 4) with rubber washers and (wing) nuts
- tap

Pump filter: containing

- 1 pump filter with flexible tube attached
- 1 brush / rough sponge to clean the ceramic candle
- 1 gauge to measure the diameter of the candle (indicating the thickness of the ceramic material)

T.B. 2.19 Chlorine-generating products

Chlorine is a chemical agent whose strong oxidizing properties are used for disinfection and decontamination. Other than its natural gaseous form, which is complicated to use and to transport, chlorine is found under the form of "chlorine-generating products". Each product is characterised by its chlorine content (active ingredient).

Chlorine-generating products

Chlorine content

The chlorine content should be labelled on the product's packaging and is expressed in:

- % of active chlorine
- chlorometric degrees (°chl)
- parts per million (ppm) or mg of active chlorine per litre.

(1°chl = about 0.3% active chlorine; 1 ppm = 1 mg/l = 0.0001% active chlorine)

Product	Chlorine content*
Sodium hypochlorite solution (bleach) 12°chl	about 4% active chlorine
Sodium hypochlorite solution (bleach) 15°chl	about 5% active chlorine
Sodium hypochlorite concentrate 48°chl	about 15% active chlorine
Chlorinated lime (bleaching powder)	about 30% active chlorine
Calcium hypochlorite / High Test Hypochlorite (often called HTH®) most often found as granules (also existing as powder or tablets)	65 to 70% active chlorine
Sodium DiChloro-isoCyanurate or NaDCC :	
• tablets	about 60% active chlorine
• granules	about 55% active chlorine

* For newly manufactured products

Storage

- Store chlorine-generating products in their original packaging which should be airtight, non-metallic or properly painted / enamelled recipients. Shelter these products from heat, light and humidity, and store them in a restricted access area (chlorine is dangerous especially for children). Never store chlorine-generating products together with organic matter, nor with combustibles because of the high risk of fire or explosion. For quantities larger than 10 kg, look for a separate storage place, away from equipment that could be damaged by corrosion.
- All chlorine-generating products have a loss in their chlorine content over time, and they generate toxic and corrosive chlorine gas, which is heavier than air. Thus storage places for chlorine-generating products should be equipped with ventilation at ground level. Never store chlorine-generating products in cellars.
- All chlorine-generating products are very sensible to storage conditions:
 - Particularly chlorinated lime and all forms of sodium hypochlorite are unstable. Sodium hypochlorite solutions should not be used if they have been stored for more than 3 months after being manufactured.
 - Calcium hypochlorite stores better with an active ingredient loss of about 2 - 5% per year under appropriate storage conditions. But under tropical conditions, the loss is usually much higher and the recommended shelf life is limited to 2 years.
 - NaDCC is by far the most stable product. Manufacturers guarantee a stable chlorine content (expiry date) of 2 years for granules, 3 years for tablets in unopened tubs and 5 years for strips, under appropriate storage conditions.

Safety, care and handling

- Any chlorine-generating product may be fatal if inhaled or swallowed. It is harmful if absorbed through the skin as it causes severe irritation. High chlorine concentrations are extremely destructive to the mucous membrane tissues, upper respiratory tract, eyes and skin. In case of contact with the eyes, rinse immediately with plenty of clean running water and seek medical advice.
- When handling any chlorine (-generating) product (e.g. opening drums, preparing and/or manipulating solutions), use a sheltered but well ventilated location and wear suitable protective gear such as rubber gloves, a plastic apron and eye / face protection.
- Never mix calcium hypochlorite with anything but water.
- Never mix calcium hypochlorite with NaDCC because toxic and explosive tri-chloramine gas may be generated.
- When purchased locally and in large quantities, calcium hypochlorite often comes in 40 - 50 kg drum containers. All containers should always be stored in the upright position. They should not be dropped, rolled or skidded in any case due to the risk of fire and explosion.
- When measuring calcium hypochlorite or NaDCC granules, only use a plastic, glass or enamelled measuring device which is completely clean, dry and free from any foreign matter, because of the risk of fire and explosion.
- Chlorine-generating products should not be brought into contact with acids, vinegar, toilet bowls cleaning agents or any other cleaning agents (e.g. detergents) due to the risk of releasing toxic chlorine fumes. Contact should also be avoided with beverages or any combustible material including paper, rags, tobacco, oil based products and any form of heat like matches, flames, lighted cigarettes because of the risk of fire and explosion.
- When chlorine-generating products are spilled, wash them thoroughly down with water and do not allow them to remain in contact with any organic or combustible matter like cloth, paper, oil.

Remarks

- In case chlorine-generating products are bought locally, it's important to ask for a certificate of their composition because all products aren't suited for drinking water. Also verify the UN transport code as it can give an indication on the kind of chlorine-generating product that is purchased (calcium hypochlorite suited for drinking water has the codes UN 1748 or UN 2880). It is important as well to buy these products in closed and sealed containers from reliable suppliers or manufacturers.
- Calcium hypochlorite (HTH®) and Sodium DiChloro-isoCyanurate (NaDCC) are recommended as chlorine-generating products because of their good stability and high chlorine content.
- NaDCC dissolves quickly and completely into a clear solution as it is effervescent, while the insoluble chalk of calcium hypochlorite gives a cloudy solution and leaves a deposit that can lead to scaling. The calcium can potentially provoke a bad taste of the treated water.
- Calcium hypochlorite is more corrosive than NaDCC and the risk of fire is higher (fires of spontaneous origin have already been reported). As calcium hypochlorite is less safe than NaDCC, its international (air) transport regulations are more strict.
- If large quantities of potable water have to be treated with NaDCC, it is recommended to use the granular form (T.B. 2.20 and 2.21). For individual or household treatment, NaDCC tablets can be used, as they exist for different quantities of water (e.g. 1 / 2 / 5 / 10 / 20 - 25 l). As these tablets contain a fixed amount of active chlorine to treat waters with varying chlorine demand, it's important to verify the Free Residual Chlorine concentration prior to distribution / consumption (T.B. 2.21) and adapt the dosage accordingly.
- A field test kit exists to make a good estimation of the actual chlorine content of (old) chlorine-generating products. Ask more information to your technical referent.

T.B. 2.20 Preparation and use of chlorine solutions for disinfection

Chlorine-generating products under granular or tablet form often need to be dissolved in clean water to obtain a certain required solution concentration. Sodium hypochlorite solutions need to be diluted because their chlorine concentration is most often too high. Once dissolved or diluted correctly, the different chlorine-generating products will result in chlorine solutions with similar disinfection properties, but their effectiveness might still vary a bit. The different chlorine concentrations that are often used by aid-agencies have all their own respective purposes.

Preparation

From powder or granular product: HTH®, NaDCC, chlorinated lime

- Check the concentration of the chlorine-generating product (% of active chlorine).
- Determine the weight of the chlorine-generating product that is required to make 1 l of solution, using the following formula:

$$X = Y \times N \times (100/C)$$

With X = grams of product to be added per litre of water to reach the desired solution concentration (g/l)

Y = desired solution concentration (%)

N = 10 g/l, equal to the amount of pure chlorine (active ingredient 100%) needed to make 1 litre of 1% mother solution

(calculation: 1 l of water weighs 1000 g; 1% of 1000 g = 10 g, thus 1% solution = 10 g/l)

C = concentration of the product's active chlorine, as mentioned on the packaging (%)

- Pour the required weight of chlorine-generating product in the determined amount of clean water. The opposite (water on chlorine) is not allowed as this can induce violent chemical reactions.

Example 1:

Make 1 litre of 1% mother solution with calcium hypochlorite (HTH®) containing 65% active chlorine

$$\rightarrow X = 1 \times 10 \times (100/65) = 15.4 \text{ g/l}$$

\rightarrow which is about 15 gram of HTH® per litre of water or 1 level scoop/l (or 1 soupsoon/l).

Example 2:

Make 1 litre of 1% mother solution with Sodium DiChloro-isoCyanurate (NaDCC) granules containing 55% active chlorine

$$\rightarrow X = 1 \times 10 \times (100/55) = 18.2 \text{ g/l}$$

\rightarrow which is about 18 gram of NaDCC per litre of water.

From liquid chlorine-releasing compounds: sodium hypochlorite (bleach) having 4 or 5% active chlorine, sodium hypochlorite concentrate having 15% active chlorine.

- Check the concentration of the sodium hypochlorite (% active chlorine).
- Determine the total parts of water that are required in which the sodium hypochlorite needs to be dissolved, according to the following formula:

$$TP = (M/N) - 1$$

With TP = total parts of water required

M = concentration of the sodium hypochlorite active chlorine, as mentioned on the packaging (%)

N = required solution concentration (%)

- Add one part of sodium hypochlorite to the amount of water required.

Example 3:

Make 1 litre of 1% mother solution with sodium hypochlorite (bleach) containing 5% active chlorine

$$\rightarrow TP = (5/1) - 1 = 5 - 1 = 4$$

\rightarrow Take one part sodium hypochlorite (5%) and add to 4 parts of water. In this case, add 0.2 l of concentrated solution to 0.8 l of water (1 l of solution/5 parts = 0.2 l of bleach; thus 0.2 l of bleach x 4 parts of water = 0.8 l of water).

Example 4:

Make 1 litre of 0.2% solution with sodium hypochlorite concentrate containing 15% active chlorine

$$\rightarrow TP = (15/0.2) - 1 = 75 - 1 = 74$$

→ Take one part concentrated solution and add to 74 parts of water. In this case, add 13 ml of concentrated solution to 987 ml of water (1000 ml of solution/75parts = 13.3333 ml of concentrate; thus 13.3333 ml of concentrate x 74 parts of water = 987 ml of water).

Use**Disinfection of water**

For chlorinating drinking water, a 1% chlorine mother solution (also called stock solution) is prepared first, whichever chlorine-generating product is used. The tables hereunder present the procedures to prepare a 1% mother solution starting from different chlorine-generating products. The quantity of 1% mother solution that needs to be added to disinfect a measured volume of water is then determined by the modified Horrocks test (T.B. 2.21).

With recommended chlorine-generating products:

Starting with	Preparation	Remarks
Calcium hypochlorite (HTH®) with 65 - 70% active chlorine	15 g per l of water or 1 level scoop/l (1 soupsoon/l)	Let the calcium deposit settle and use only the supernatant
Sodium DiChloro-isoCyanurate (NaDCC) with 1 g active chlorine per tablet	10 tablets per l of water	Ensure that the excipients in the tablets are non-toxic
Sodium DiChloro-isoCyanurate NaDCC) granules with 55% active chlorine.	18 g per l of water	Ensure that the excipients in the granules are non-toxic

When none of the above chlorine-generating products are available:

Chlorinated lime with 30% active chlorine	33 g per l of water or 2 level soupsoons/l	Let the lime deposit settle and use only the supernatant
Sodium hypochlorite (bleach) with 5% active chlorine	200 ml per l of solution or 1 volume of bleach for 4 volumes of water	
Sodium hypochlorite (bleach) with 4% active chlorine	250 ml per l of solution or 1 volume of bleach for 3 volumes of water	Only if manufactured very recently (< 3 months) and only if stored under proper conditions.
Sodium hypochlorite concentrate with 15% active chlorine	67 ml per l of solution or 1 volume of concentrate for 14 volumes of water	

Disinfection in a health structure

Different solutions with different chlorine concentrations are used in health structures. The chlorine concentration in the solution depends on the usage of the disinfecting solution. These solutions are essential to maintain a hygienic and safe environment within a health structure and even more during outbreaks of infectious diseases like cholera, shigellosis, Ebola or Marburg. An in-depth description of how to use these solutions properly for these highly infectious diseases can be found in the respective guidelines (section 8.5 Further reading).

The 6 main chlorine solutions are: 2%, 1%, 0.5%, 0.2%, 0.1%, 0.05%. They can be prepared by using the formulas presented above. In the context of these guidelines:

2%	<ul style="list-style-type: none">• Disinfection of corpses in case of a cholera outbreak• Disinfection of stools and vomit in case of a cholera outbreak	T.B. 8.01
1%	Used as a mother solution to be diluted for: <ul style="list-style-type: none">• disinfecting drinking water• other purposes like cleaning and disinfection of a:<ul style="list-style-type: none">- well- flexible reservoir	T.B. 2.21; T.B. 2.23 T.B. 2.03 T.B. 2.37
0.5%	<ul style="list-style-type: none">• Disinfection of corpses in case of Viral Haemorrhagic Fevers (e.g. Ebola, Marburg) or Sars outbreaks• Disinfection of stools, vomit, urine, body fluid spills, gloved hands in case of Viral Haemorrhagic Fever outbreaks	T.B. 8.01
0.2%	<ul style="list-style-type: none">• Disinfection of floors, walls, surfaces, beds, objects, latrines in case of a cholera outbreak• Disinfection and cleaning of:<ul style="list-style-type: none">- floors in case of rodents associated diseases or in case of an outbreak of lice-associated diseases	T.B. 1.08
0.1%	<ul style="list-style-type: none">• Disinfection and cleaning of:<ul style="list-style-type: none">- tankers, pipes, pumps- showers- washing facilities- collective dustbins and drainage holes- reusable sharps containers- drop pipe, slab and surroundings of a sharps pit- soft waste bins- organic waste bins and the slap of an organic waste pit	T.B. 2.34 T.B. 4.01 T.B. 4.02 T.B. 5.01 T.B. 6.01 T.B. 6.02; T.B. 6.03 T.B. 6.05; T.B. 6.06 T.B. 6.08
0.05%	<ul style="list-style-type: none">• Scrubbing the walls of a well• Disinfection and cleaning of:<ul style="list-style-type: none">- recipients of ceramic candle filters- open tanks- lorries / carts (waste transportation)• Disinfection of hands, skin, clothing, bedding, washing up in case of a cholera outbreak• Disinfection of household gloves, aprons, goggles, clothing, bedding	T.B. 2.03 T.B. 2.18 T.B. 2.37 T.B. 5.03

Remarks

- Chlorine reacts with metals, leading to a high chlorine consumption and a strong oxidation of the metals. Hence, never prepare chlorine solutions in metallic containers (unless properly enamelled).
- Chlorine must always be poured in the water, but the opposite (water on chlorine) is prohibited due to the risk of violent exothermic reactions that could lead to serious injuries.
- The use of chlorinated lime, sodium hypochlorite containing 4 - 5% active chlorine or sodium hypochlorite concentrate containing 15% active chlorine is only recommended if NaDCC and HTH® are not available.
- A 2% chlorine solution should only be used for restricted purposes and should never be sprayed in enclosed facilities because of its high concentration and the risks associated with the release of toxic chlorine gas in contact with the air or organic matter.
- Chlorine solutions should not be poured into a toilet or a latrine as it will stop the natural decomposition in the septic tank or pit, filling them up more rapidly and generating extremely bad odours. However, in isolation units during epidemics of cholera, shighela, Ebola or Marburg, it is recommended to use chlorine solutions to disinfect all the patients' excreta (section 8.5 Further reading).
- Calcium hypochlorite (HTH®) and chlorinated lime leave a deposit, thus only the supernatant should be used and the deposit disposed of in a shallow pit.
- Less corrosive products exist to disinfect medical equipment or surfaces in long-term health structures.

T.B. 2.21 Batch chlorination of drinking water

Chlorination is one of the best methods for disinfecting drinking water because it is relatively simple, effective, easy to monitor and it has a remnant protective effect. Only the chlorination of a known water volume in a reservoir is presented here, known as batch chlorination. The principle is to add enough chlorine to eliminate pathogens contained in the water (mainly bacteria and chlorine sensitive viruses), and to leave a small fraction of chlorine available for dealing with possible recontamination. Chlorination requires staff being trained in the dosage technique and in its monitoring.

Operation

To determine how much 1% chlorine mother solution that needs to be added to a measured volume of water, use the modified Horrocks test:

- Prepare 1 litre of 1% chlorine mother solution (T.B. 2.20).
- Measure the pH of the water to be treated in order to determine the needed contact time (T.B. 2.22).
- Take at least 4 non-metallic containers of known volume (preferably 20 l plastic buckets or jerrycans), all having a cover.
- Clean the containers and their cover 3 times with the water to be treated. When the containers are soiled inside, the dirt can be removed the first time by a clean brush (or clean hands when they fit inside) and water, the remaining times only rinse with the water.
- Fill all the containers with the same amount of water to be treated (e.g. 20 l), put their cover on and label them (1 to 4).
- Add to each bucket a progressively increasing dosage of 1% chlorine mother solution with a graduated sterile syringe :
 - Container 1: 1.0 ml
 - Container 2: 1.5 ml
 - Container 3: 2.0 ml
 - Container 4: 2.5 ml
- Put the covers back on and wait for the chlorine to react during the minimum required contact time:
 - For a pH < 8, minimum 30 minutes
 - For a pH > 8 and/or a water temperature < 10 °C, minimum 60 minutes (T.B. 2.22).
- Measure the Free Residual Chlorine (FRC) concentration in each container (T.B. 2.22).
- If the pH < 8, choose as reference the container where the Free Residual Chlorine concentration is between 0.2 and 0.5 mg per litre. In case two following containers would have a FRC in between 0.2 and 0.5 mg/l, opt for the one with the highest concentration.
- If the pH > 8, choose as reference the container where the FRC concentration is between 0.4 and 1.0 mg per litre. In case two following containers would have a FRC in between 0.4 and 1.0 mg/l, opt for the one with the highest concentration.
- Repeat the Modified Horrocks test with higher 1% mother solution dosages if none of the FRC measurements are in between 0.2 - 0.5 mg/l (0.4 - 1.0 mg/l; depending on the pH).
- Extrapolate the determined dose of 1% mother solution to the volume of the water reservoir that will be used.
- Pour the solution in the reservoir, ideally while filling it up to obtain a homogenous repartition of the solution in the water and mix well (if still needed).
- Wait for the required contact time (depending on the pH and temperature of the water).
- Control the FRC at the level of the taps before the water is distributed to the beneficiaries. Slightly adjust the reservoir's mother solution dosage, if needed.

Example

Chlorination of a 2,000 l water reservoir

- Follow the steps of the modified Horrocks test as described above for 20 l recipients.
- The pH is measured to be 7.2 and the water temperature is at 20 °C. The FRC levels of the water in the containers are measured after the required 30 minutes contact time, and are respectively as follows:

Container	Added 1% mother solution	Measured FRC concentration
1	1.0 ml	0.0 mg/l
2	1.5 ml	0.1 mg/l
3	2.0 ml	0.4 mg/l
4	2.5 ml	1.0 mg/l

- The chosen reference dose will therefore be the one of recipient number 3, because its obtained FRC concentration of 0.4 mg/l is between 0.2 - 0.5 mg/l.
- If 2 ml of 1% chlorine solution is needed to chlorinate 20 l of water at the correct dosage, then 100 times as much 1% mother solution will be required to chlorinate 2,000 l of the same water quality, thus $100 \times 2\text{ml} = 200\text{ ml}$ of 1% mother solution.
- The doses of 1% mother solution given in this example are only an indication. It may happen that the chlorine amount needed to treat the water in the field is very different from this example.



Key

1. Beaker with 1% chlorine mother solution
2. Recipients with water to be treated
3. Lid of the recipients
4. Syringe with 1% chlorine mother solution

Input

- Several containers of the same known volume, with lid
- Syringe (5 – 10 ml)
- 1% chlorine mother solution
- Pool tester with cover
- DPD 1, (DPD 3) and Phenol Red tablets
- Watch (to measure the contact time)
- Protective gear (gloves, apron, goggles/face shield)
- (Turbidity tube)

Remarks

- Chlorination is effective against most enteric bacteria and plenty but not all viruses (e.g. Hepatitis E). At the doses normally used for potable water treatment, chlorine isn't really effective against protozoan cysts and helminth eggs.
- The most practical way to guaranty chlorine's best effectiveness is to monitor the pH, the turbidity and the Free Residual Chlorine concentration after the optimum contact time. Note that the chlorine demand may vary over time with (unexpected) changes in the amount of organic matter in the water. It is thus important to monitor the FRC concentration, the pH and the turbidity frequently in order to be able to adjust the water treatment accordingly.
- Particles in suspension (turbidity) can protect micro-organisms from chlorine disinfection. Even with a correct Free Residual Chlorine concentration, many harmful micro-organisms may survive. Water to be chlorinated must contain as little visible suspensible material as possible and when measured (e.g. with a turbidity tube; T.B. 2.13), it should be less than 5 (N)TU (less than 20 (N)TU in acute emergencies). If the turbidity exceeds the recommended values, a pre-treatment such as sedimentation (natural or assisted; T.B. 2.14; 2.15; 2.16) or filtration (T.B. 2.17) should be done before the chlorination process.
- Chlorination is less effective if the pH of the water is above 8 (T.B. 2.22), therefore a doubling in contact time (60 minutes) and FRC (0.4 - 1.0 mg/l) is required. If the temperature is below 10 °C, the contact time should also be doubled (60 minutes), but the Free Residual Chlorine concentration should still be between 0.2 and 0.5 mg/l if the pH is lower than 8.
- If recipients with a tap are used, do not use the tap to fill the pool tester, as it might be contaminated and lead to false results.
- The taste or odour of chlorine in water is not a proof of the presence of Free Residual Chlorine (FRC). It could be due to the presence of Combined Residual Chlorine (CRC), which has a less disinfecting capacity and which cannot be measured with DPD 1 tablets. The CRC can be determined as follows:
 - Add an additional DPD 3 tablet in the compartment in which a DPD 1 tablet has already been dissolved to determine the FRC.
 - Read the Total Residual Chlorine (TRC) concentration as soon as the DPD 3 tablet has dissolved.
 - Determine the CRC by subtracting the FRC from the TRC.
- A verification of the TRC and CRC once in a while is recommended, certainly if NaDCC is used as chlorine-generating product (T.B. 2.19).

T.B. 2.22 Monitoring chlorination

The simplest way to monitor the effectiveness of chlorination is to measure the Free Residual Chlorine (FRC) concentration in the drinking water. The presence of FRC in the treated water (after 30 or 60 minutes contact time, depending on its pH and temperature) indicates that enough chlorine has been added to satisfy the chlorine demand and to create Combined Residual Chlorine (CRC), whilst still leaving an excess of available free chlorine. The remaining FRC is available to deal with possible recontamination in the distribution system or during handling.

Operation

The measurement of Free Residual Chlorine (FRC) concentration and pH is most easily done using a comparator, commonly called a “pool tester”.

- Remove the lid of the pool tester.
- Rinse the inside of the pool tester, including its lid, 3 times with the water to be tested. This is to be sure that all remaining residues of previous tests are removed.
- Fill the 3 compartments to the top with the water to be tested, without dipping it in its recipient.
- Tear the foil strip open and put one Phenol Red tablet in the small left hand compartment without touching it. This is to measure the pH.
- Tear the foil strip open and put one DPD 1 tablet in the small right hand compartment without touching it. This is to measure the Free Residual Chlorine.
- Replace the lid tightly with the arrows pointing towards the coloured reference scale. It is normal that some liquid is pressed out of the pool tester.
- Shake gently until the tablets are completely dissolved. This may take about 20 seconds, depending on the water temperature.
- Read the results immediately in natural day light, comparing the colours in the outer compartments (containing the water samples with the dissolved tablets) with the colour scale of the central compartment (reference).
- Empty the pool tester and rinse it again with clean disinfected water to remove the residues of the analysis, in order to prevent inaccurate results at the next measurement.

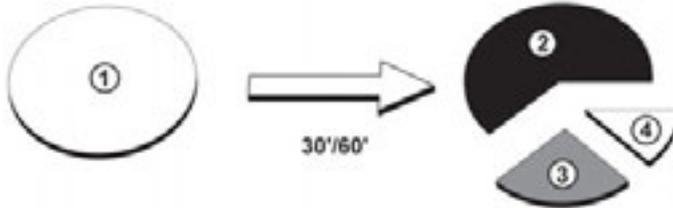
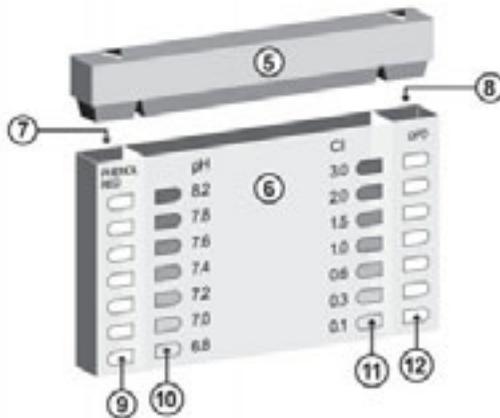
Results

- Measuring the pH is necessary to interpret the FRC concentration correctly.
- Measuring a Free Residual Chlorine concentration after the required contact time is a good indicator that the chlorination is complete:
 - The added chlorine has been reacting with the organic matter present in the water, including micro-organisms (e.g. bacteria) and is therefore partly consumed (chlorine demand).
 - A part of the added chlorine has combined with certain elements in the water (mainly nitrogen) and forms the Combined Residual Chlorine (CRC), which isn't effective to react rapidly against a post-contamination.
 - The remaining residual chlorine is free in the water (FRC) and will immediately react with a post-contamination (remnant effect). The following results should be obtained in low-income countries.

Water characteristics	Contact time	FRC
pH < 8	30 minutes	0.2 - 0.5 mg/l
pH > 8	60 minutes	0.4 - 1.0 mg/l
Temperature < 10 °C (pH <8)	60 minutes	0.2 - 0.5 mg/l

The required contact time is needed to allow the completion of the disinfection process. The FRC concentration shouldn't be too low in order to provide a good protection against post-contamination. It shouldn't be too high either as this might induce the refusal of the beneficiaries to consume the water (not used to the odour or taste of chlorinated water, although they can also be caused by the CRC).

WARNING: a Free Residual Chlorine concentration above 10 mg/l can cause bleaching of the DPD colour (no colour to be observed), wrongly indicating zero residual chlorine.

A**B****Key****Input**

A. Chlorine decomposition in water
 B. Pool tester

1. Chlorine added
2. Chlorine consumed
3. Combined Residual Chlorine (CRC)
4. Free Residual Chlorine (FRC)
5. Cover
6. Central compartment
7. pH compartment (Phenol Red tablet)
8. FRC compartment (DPD 1 tablet)
9. pH reading scale
10. pH reference scale
11. FRC reference scale
12. FRC reading scale

- 1 pool tester with lid
- Phenol Red tablets (Phenol Red must be marked in green on the packaging)
- DPD 1 tablets (DPD 1 must be marked in green on the packaging)
- Optional DPD 3 tablets (DPD 3 must be marked in green on the packaging)
- Water to be tested

Remarks

- The pool tester can be used as well to perform the modified Horrocks test (T.B. 2.21), as for monitoring the Free Residual Chlorine (FRC) concentration of an operational water supply system.
- The monitoring of FRC for a water supply system should be done on a regular basis (at least daily). It is recommended to let the water flow for a few moments (e.g. 30 seconds) before taking it from a tap. If this monitoring shows a constant discrepancy between the actual results and the expected range, another modified Horrocks test must be undertaken.
- It's important that the quality of the water to be tested doesn't change during the rinsing and filling steps of the modified Horrocks test (T.B. 2.21), as this might result in false measurements.
 - The water can be taken from the recipient and introduced to the pool tester by means of a sterile syringe (e.g. 50 ml). The Free Residual Chlorine would react immediately with a contaminated syringe, thus indicating a lower FRC concentration than is actually present in the treated water. It is therefore of utmost importance not to touch the outside of the syringe that comes in contact with the treated water, nor to place it on a contaminated surface (put it carefully back in its packaging).
 - An alternative to the sterile syringe is to gush the water from the water container directly into the pool tester. This is a rapid manner, but a lot of water will be spilled, meaning the whole procedure, including the rinsing and filling of the containers, will have to be repeated if the first round of the modified Horrocks test doesn't provide acceptable results.
 - Never put the pool tester into the water container as its outside is contaminated.
 - If recipients with a tap are used, do not use the tap to fill the pool tester, as it might be contaminated and lead to false results.
- For the same reason should the tablets, the inside of the pool tester or the inside part of its cover never be touched. Never use tablets that have fallen on the ground.
- The printing "DPD 1" / "Phenol Red" on the foil strips must be in green, meaning that the tablets are rapid dissolving. Tablets of foil strips with black printing should never be employed with the standard pool tester that is used on the field for monitoring chlorination.
- The tablets normally have a shelf life of minimum 5 years. The expiry date should be printed on the outside of their outer (cardboard) packaging, and for some brands on the foil strips. Other brands have the manufacturing date indicated on the foil strips under the form of a code: "A" is the year 2003, "B" is 2004. The two numbers after the capital letter indicate the manufacturing month.
- Only whole tablets must be used. Do not use broken tablets (bad storage or while opening packaging).
- Do not use tablets that disintegrate on opening or have lost their colour (dull grey / brown instead of bright white for DPD 1, and dull brown instead of bright orange for Phenol Red).
- Expired or damaged tablets can be disposed of with normal waste.
- Read the results within 60 seconds once the tablets have dissolved to be sure of a reliable measurement. The results are not guaranteed after this limited period.
- Read the results under good illumination conditions, meaning natural day light. Sun glasses must be taken off. Ideally, the reading should be made on a white surface (e.g. a tent wall), but pointing the pool tester towards the sky, away from the sun, can do as well.
- The pH must systematically be measured before starting chlorination, as a pH > 8 requires a higher contact time and a higher FRC concentration (see above). The pH of (surface) water may vary significantly over time, so it needs to be controlled frequently.
- Comments on the pH of water:
 - pH = 7: neutral; pH < 7: acidic; pH > 7: alkaline (or basic).
 - pH values under 6.8 will always cause a yellow colouration, whereas pH values above 8.2 will cause a red colouration with the Phenol Red method of the standard pool tester used on the field.
- The taste or odour of chlorine in water is not a proof of the presence of Free Residual Chlorine (FRC). It could be due to the presence of Combined Residual Chlorine (CRC), which has a less disinfecting capacity and which cannot be measured with DPD 1 tablets. The CRC can be determined as follows:
 - Add an additional DPD 3 tablet in the compartment in which a DPD 1 tablet has already been dissolved to determine the FRC.
 - Read the Total Residual Chlorine (TRC) concentration as soon as the DPD 3 tablet has dissolved.
 - Determine the CRC by subtracting the FRC from the TRC.
- A verification of the TRC and CRC once in a while is recommended, certainly if NaDCC is used as chlorine-generating product (T.B. 2.19).
- Colour-blind people might have problems reading the FRC, TRC and/or pH with the pool tester.

T.B. 2.23 Controlled bucket chlorination

Water that is collected by individuals from an unprotected and/or contaminated source (e.g. open well, lake, river, flooded borehole) is disinfected directly in their own recipient. It is an effective method as long as the water isn't too turbid. As controlled bucket chlorination is labour intensive, it should be restricted to short-term emergency use only. In closed settings, bucket chlorination should be replaced rapidly by a batch chlorination system in reservoirs that are connected to tapstands, whereas in open (rural) settings, protected water sources are the preferred option.

Preparation

- Set up the bucket chlorination system by training several chlorinators and their supervisors. Typically one supervisor can manage a maximum of 30 chlorinators, although this will vary according to the situation. In practice, one chlorinator should be able to treat at least 2 buckets of water per minute.

Chlorinator tasks

- Preparation of the 1% chlorine solution.
- Evaluating the volume of the people's water recipient.
- Adding the corresponding volume of 1% chlorine solution to the people's recipient.
- Recording the details of the dosage.
- Providing basic information on chlorination to the beneficiaries; e.g. the need to wait for 30 minutes before using the water (if pH < 8).

Supervisor tasks

- Responsible for the chlorination teams and for the promoting team (promotion of the chlorination system to the beneficiaries).
 - Perform turbidity, pH and chlorine jar tests (modified Horrocks test).
 - Monitoring the performance of the chlorinators; checking of the chlorinators' records and (randomly) spot checking the chlorinated water inside the users' recipients through Free Residual Chlorine measurements.
 - Monitoring the water source for any changes in turbidity, pH or chlorine demand.
- Locate the chlorinators next to areas where people collect drinking water. In areas where there are many water points, try to organise with the community a smaller number of focal water points that are accessible to all and that can provide enough water to cover the demand.
 - Launch within the community an information campaign to promote this chlorination method.

Operation

- Measure the turbidity (T.B. 2.13) and pH of each individual water source (T.B. 2.22) to determine the relevance of chlorination and the appropriate contact time. When the turbidity of the water to be treated is high, chlorination isn't effective. The recommended turbidity value for efficient chlorination is set at 5 (N)TU, although turbidities up to 20 (N)TU are acceptable during the acute phase of an emergency. In case these values are exceeded, the amount of suspended particles in the water has to be reduced by natural or assisted sedimentation (T.B. 2.16) and/or filtration (T.B. 2.17).
 - Prepare a 1% chlorine solution (T.B. 2.20), preferably on a daily basis because correct storage conditions will most probably be lacking. Use non-metallic containers because metal consumes chlorine and will corrode rapidly.
 - Carry out the chlorine jar test (modified Horrocks test; T.B. 2.21) for each individual water source.
 - Determine the volume of the different water-collecting recipients from the beneficiaries. In case it proves to be difficult to estimate the volume of their recipients, a weighing scale can be used (1 kg = 1 litre of water).
 - Inject with a syringe the appropriate amount of 1% mother solution, related to the volume of each individual recipient and based on the results of the modified Horrocks test.
 - Do random tests on several containers to verify if a correct Free Residual Chlorine concentration (FRC) is reached:
 - if pH < 8, FRC of 0.2 - 0.5 mg/l after a minimum contact time of 30 minutes.
 - if pH > 8, FRC of 0.4 - 1.0 mg/l after a minimum contact time of 60 minutes because chlorination is less effective if the pH is above 8.
- Insufficient FRC concentrations of the collected water can be due to dirty containers, thus resulting in a higher chlorine consumption (higher chlorine demand; T.B. 2.22).



Key

1. 1% chlorine solution
2. Syringe with 1% chlorine solution
3. Recipient of a beneficiary

Input

- Chlorine-generating product
- Protective clothing: gloves, aprons, goggles or face shield and boots
- Measuring cylinder 1 l
- 20 l jerrycans for 1% solution storage
- 20 l buckets for the Modified Horrocks test (chlorine jar test)
- Pool testers with DPD 1 and Phenol Red tablets
- Range of syringes (e.g. 5, 10 ml)
- Turbidity tube

Remarks

- Keep chlorine-generating products in their original packaging which should be airtight, non-metallic or properly painted / enamelled containers. Shelter these products from heat, light and humidity, and store them in a restricted access area (chlorine is a dangerous product). Never store chlorine-generating products together with organic matter (e.g. food), nor with combustibles because of the risk of fire or explosion. For quantities larger than 10 kg, look for a separate storage place, away from equipment that could be damaged by corrosion (chlorine is a strong oxidant).
- It is recommended to provide to each chlorinator a table indicating the amount of 1% chlorine solution that needs to be injected per volume of recipient (based on the modified Horrocks test); e.g. 2ml of 1% chlorine solution for a recipient of 8 litres, 2.5 ml per 10 l, 3 ml per 12 l, 4 ml per 16 l, 5 ml per 20 l.
- The syringes for chlorine dosing are susceptible to wear, so sufficient supplies should be stored.
- The transport between the water point and a person's home can be sufficient for both the mixing and the required contact time. Where this is not the case, a strategy will have to be implemented that insures the appropriate contact time.
- A distribution of clean recipients, in plastic material, such as jerrycans may be necessary to ensure that the population has proper and clean transportation and storage means. Moreover, as the recipients will all be of the same capacity, the chlorination will be easier. In case it isn't possible to provide clean recipients, the cleaning of the beneficiaries' containers should be envisaged.
- In situations where water is sold, it may be advisable that the water sellers are involved in the chlorination process, to ensure that the sold water is disinfected.
- Key users can be enabled to give feedback on water quality, if they are equipped with a pool tester (T.B. 2.22) and trained for checking the FRC concentration.
- Several products combining a coagulant, potentially some flocculants, and a disinfectant are available under the form of tablets or sachets. These products are intended for individual households or small scale (community) water treatment. A certain vigilance is required with these products because fixed doses of different chemicals are added to a determined amount of raw water that can have any quality, without performing a jar test (T.B. 2.15) or a Modified Horrocks test (T.B. 2.21). The Free Residual Chlorine concentration (T.B. 2.22) of the treated water should at least be analysed, and preferably also its residual aluminium or iron concentration (depending on the coagulant used in the product). In case any of the measured values are outside the normally used standards (indicators), advice should be sought from your technical referent. Besides the potential technical issues, a lot of attention should also go to the distribution procedure of these products. It is also important to verify if the beneficiaries use the product properly. Hence, a promotion and training campaign will be of utmost importance.

T.B. 2.24 Basic topographic survey

In order to design a water supply system, it is necessary to conduct a survey identifying the topography of the proposed route. This will permit to calculate the characteristics of a water pipeline that will be gravity-fed or pressurised by a pump. The length is preferably measured by means of a long measuring tape, while the height difference can be calculated based on the length and the vertical angle in between the two extremities of the water supply system. The topographic surveys described hereafter are for simple and rather short water supply systems.

Procedure

A. Calculating the height difference on a hill with a single and rather constant slope

- Measure the eyesight height of the surveyor.
- Determine by means of a long measuring tape (e.g. 50 m) the distance in between the two extremities of the water supply system, namely the water source and the utility point. If still needed, it should be verified if the proposed route will permit the excavation for a potential underground installation of the pipe.
- Stand at the lower extremity of the water supply system (e.g. river), hold the Abney level to the eye and sight the other extremity of the water supply system (e.g. reservoir) by centring the cross-hair against the target.
- Adjust the index arm until the bubble (visible in half of the field-of-view) is centred against the cross-hair and block the index arm with its fixing screw.
- Read the vertical angle α on the arc in degrees
- Calculate the height difference in between the extremities of the water supply system by using the following formula:

$$H = L \times \sin(\alpha) + h$$

With H = height difference in between the extremities of the water supply system

L = distance in between the two extremities of the water supply system

α = angle between the horizontal level (measured at the eyesight of the surveyor standing at the lower extremity) and the upper extremity of the water supply system

h = eyesight height of the surveyor

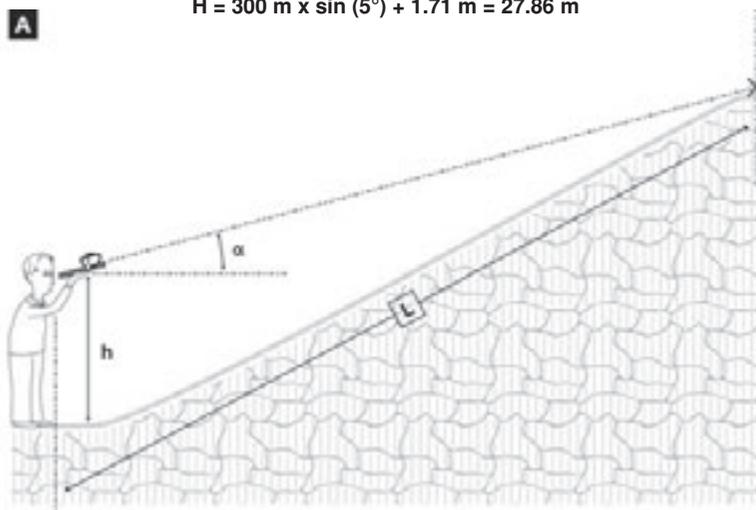
Example:

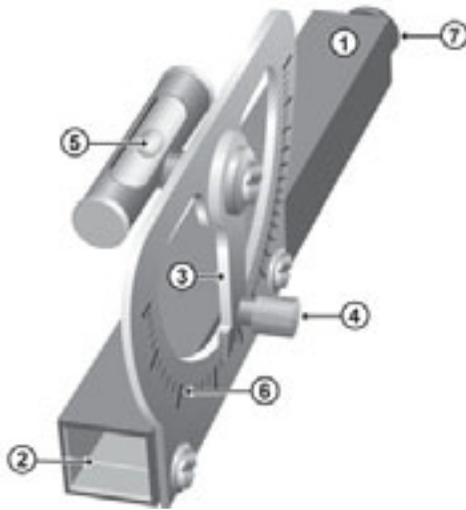
L = distance measured in between the river and the reservoir up the hill = 300 m

α = measured angle between the river and the outlet of the reservoir up the hill = 5°

h = eyesight height of the surveyor = 1.71 m

$$H = 300 \text{ m} \times \sin(5^\circ) + 1.71 \text{ m} = 27.86 \text{ m}$$





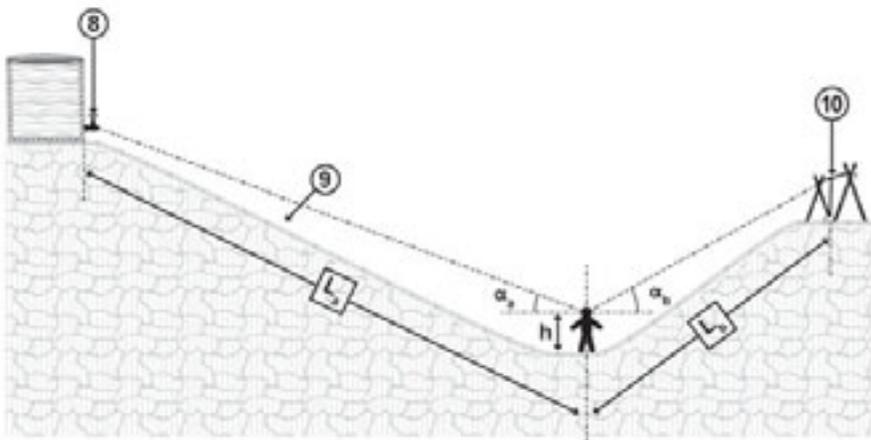
Key

1. Abney level
2. Cross-hair
3. Index arm
4. Fixing screw
5. Air bubble centred against cross-hair
6. Arc
7. Ocular
8. Outlet of reservoir
9. Topography of the area
10. Tapstand

Input

- Abney level
- Long measuring tape (e.g. 50 m)
- Notebook and pen / pencil
- Calculator

B



B. Calculating the height difference when a short water supply system passes through a "small" valley

- In this case, measurements must be taken from the bottom of the valley, first in the direction of one extremity (a) of the water supply system and secondly in the direction of the other extremity. The same procedure as described in A must then be followed twice. The height difference between the two extremities is then represented by the difference (ΔH) between $H_{(a)}$ and $H_{(b)}$.

Example:

- $L_{(a)}$ = distance in between the bottom of the valley and the extremity (a) (e.g. outlet of a reservoir) = 250 m
- $\alpha_{(a)}$ = angle measured in between the bottom of the valley and extremity (a) = 7.2°
- $L_{(b)}$ = distance in between the bottom of the valley and the extremity (b) (e.g. a tapstand) = 150 m
- $\alpha_{(b)}$ = angle measured in between the bottom of the valley and extremity (b) = 7.8°
- h = eyesight height of the surveyor = 1.71 m

$$H_{(a)} = 250 \text{ m} \times \sin (7.2^\circ) + 1.71 \text{ m} = 33 \text{ m}$$

$$H_{(b)} = 150 \text{ m} \times \sin (7.8^\circ) + 1.71 \text{ m} = 22 \text{ m}$$

$$\Delta H = 33 \text{ m} - 22 \text{ m} = 11 \text{ m}$$

C. Calculating the height of a water tower

- Measure the eyesight height of the surveyor.
- Choose a reference point on a flat surface nearby the water tower from which all measurements will be taken.
- Determine the horizontal distance in between the reference point and the water tower by means of a measuring tape.
- Stand at the reference point, hold the Abney level to the eye and sight the highest part of the water tower by centring the cross-hair against the target.
- Adjust the index arm until the bubble (visible in half of the field-of-view) is centred against the cross-hair and block the index arm with its fixing screw.
- Read the vertical angle α on the arc in degrees.
- Calculate the height of the water tower by using the following formula:

$$H = L \times \text{tangent} (\alpha) + h$$

With H = height of the water tower

L = horizontal distance in between the reference point and the water tower

α = angle between the horizontal level (measured at the eyesight of the surveyor standing at the reference point) and the upper point of the water tower

h = eyesight height of the surveyor

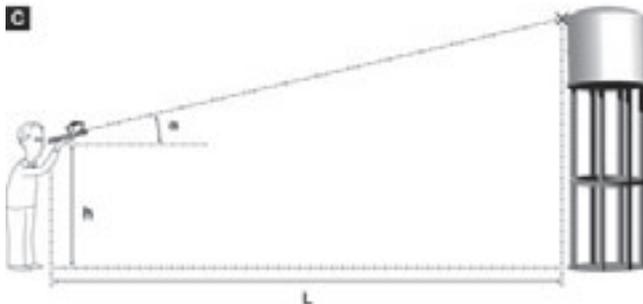
Example:

L = horizontal distance in between the reference point and the water tower = 40 m

α = angle measured in between the reference point and the water tower = 24.5°

h = eyesight height of the surveyor = 1.71 m

$$H = 40 \text{ m} \times \tan (24.5^\circ) + 1.71 \text{ m} = 20 \text{ m}$$



Remarks

- Long complicated water supply systems passing several hills fall out of the scope of these guidelines (section 2.5 Further reading).
- All formulas given are to be used with a calculator in the “degrees” mode. If the calculator is in “radians” mode, the angle should be converted in radians as well: $\text{degrees} \times \pi/180^\circ = \text{radians}$ ($\pi = 3,14$).
For example: $H = 300 \text{ m} \times \sin(5^\circ \times \pi/180^\circ) + 1.71 \text{ m} = 27.86 \text{ m}$
- When making a topographic survey of a single slope for a gravity-fed system, the available height difference (pressure) to overcome the linear and local head losses (T.B. 2.31) should be measured in between the tap height and the outlet of the reservoir. This means that standing at the tap site, the outlet of the reservoir should be targeted with the Abney level. The height of the tap should be deducted from the calculated height based on the Abney level measurement (as described above).
- To determine the maximum pressure in a gravity-fed pipeline, the maximum height difference between the lowest point in the system and the maximum water level (in the reservoir) should be measured. This maximum height difference is important to verify the pressure the pipe has to resist to when all the taps are closed. When the maximum water level in the reservoir can't be determined, its maximum height can be used as a reference.
- To be able to determine the pressure that a pump has to deliver pumping water uphill, the height difference should be measured in between the (dynamic) water level of the source and the maximum water level in the system (e.g. completely filled reservoir, highest point within the pipeline). To this pressure related to the height difference, the needed pressure to overcome the head losses (linear and local) should be added to determine the required pump capacity.
- In case the total height of a water tower has to be determined, the upper part of the reservoir should be sighted with the Abney level. However, in order to know the minimum pressure that the water tower will be able to provide, the lower part (outlet) of the reservoir should be sighted.
- The distance and the height difference can also be measured with a GPS, but be aware that the majority of these instruments only give an horizontal precision equal to 10 m and the vertical precision is even lower. So normal GPS systems aren't that suited for topographic surveys.
- The clinometer is similar to the Abney level. It has a simpler concept and is cheaper, but as the sighting is more difficult to do, the precision is less accurate than with an Abney level.
- The altimeter functions by measuring the barometric pressure differences at different altitudes (lesser atmospheric pressure at higher altitude). As varying weather can change the barometric pressure as well, the measures should be taken in a short period. An alternative is to have one mobile and one or two fixed altimeters at the extremities of the topographic area under study. By measuring at regular intervals the pressure differences at the fixed altimeters, it will be possible to add a correcting factor to the measurements of the mobile altimeter. The altimeters precision of 1 to 5 m is often not sufficient.
- The theodolite and laser are both high-precision instruments that are expensive and might require special training. The accuracy obtained with these instruments (within centimetres) is usually not needed for topographic surveys.

T.B. 2.25 Centrifugal pumps

Most motorized (combustion engine or electric) water pumps used by aid-agencies are centrifugal types. The principle of a centrifugal pump is that its spinning impellor (rotor) throws the water outwards and the empty space that is created at the centre of the impellor is filled via the “suction pipe” by new water, which is actually pushed in by the atmospheric air pressure. This new water will be thrown outwards again by the impellor, creating again an empty space at its centre and so on continuously until the pump is stopped. The velocity of the water thrown out of the impeller is partly transformed within the pump’s snail house (stator with a specific form) into pressure, thus the water can be transported at a certain flow over a certain height.

Types of centrifugal pumps mainly used by aid-agencies

Surface pumps

They will most of the time be situated above the water surface and will “suck up” the water to deliver it at higher grounds. Whatever the kind or the power of the motor driving the pump, its maximum suction height (head) is about 7 m at sea level, and decreases as the altitude rises.

- Low pressure *motor pumps* (e.g. maximum pressure of about 300 kPa or 3 bar), driven by a petrol or diesel engine, are often used in emergencies. As motor pumps are designed to work at construction sites, they can deal with very turbid water that contains small solid particles.
- Most *high pressure pumps* (e.g. > 600 kPa or 6 bar) aren’t conceived to pump turbid water.
- *Trash pumps* (T.B. 3.13) are able to pump turbid water containing solids up to 20 – 30 mm (e.g. small debris, faeces) without clogging. Their impellor blades often have sharp edges to shred soft particles.

Submersible pumps

They need to be completely submerged in the water, otherwise they stop or even break down after a short period of use. As they are completely submerged, these pumps don’t “suck up” the water, they only have to deliver (push) it. They are specifically interesting for (tube) wells that have their water level (a lot) deeper than 7 m under the surface. The flow and pressure that can be delivered, depend on the size of the pump and on the power of its electric motor (most often combined in one piece of equipment). Submersible pumps are designed to lift non-turbid water, thus solid particles in suspension will damage their impellers and pump house.

Dewatering pumps

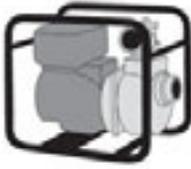
They combine to a certain extent features of the commonly used motor pumps and the submersible pumps. Dewatering pumps that are driven by electric motors, can be completely submerged or nearly completely out of the water (as long as the impeller part stays submerged). Some high quality models exist that have their electric motor cooled by the pumped water, so the motor part can stay out of the water for prolonged periods. As their inlet has to be under the water level, dewatering pumps can only deliver water, but at (relatively) high flow rates. As these pumps are designed for (very) dirty water, their delivery height is rather limited (certainly in comparison to submersible pumps in the same electric power range). Aid-agencies use them mainly to dewater hand dug wells rapidly, before the works within can start. They can also be used during well cleaning (T.B. 2.03) or to remove the sludge from assisted sedimentation reservoirs (T.B. 2.16). They can also be employed to deliver potable water from hand dug wells that are more than 7 m deep.

Pump characteristics

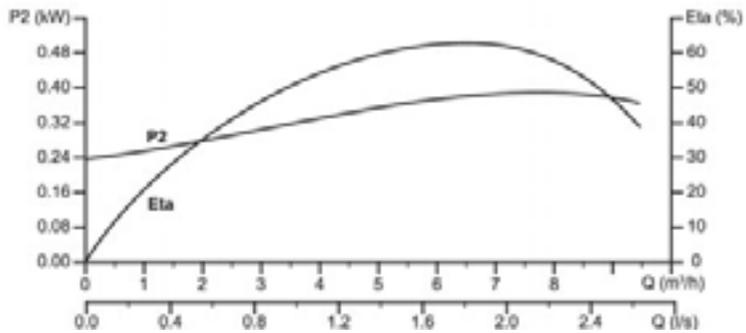
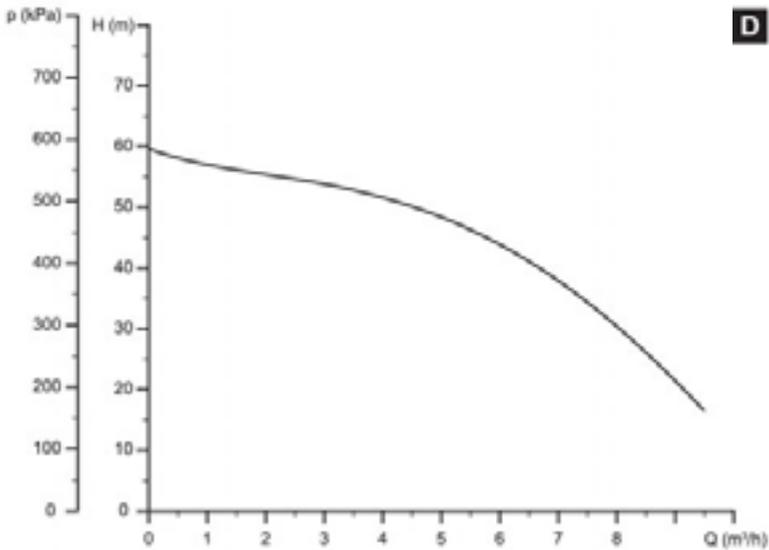
Identification plate

Every centrifugal pump should have an identification plate indicating at least two working points:

- The maximum Total Manometric Head (TMH) it can reach (at zero flow); expressed in kPa, bar, meter Water Column (mWC).
- The maximum flow it can reach (theoretical working point at TMH zero); expressed in l/s, l/min, m³/h.

A**B****C****Key**

- A. Motor pump
- B. Submersible pump
- C. Dewatering pump
- D. Pump graph (centrifugal pumps)



Characteristics curves (graphs)

- ***pQ (upper part of the graph)***: The pQ curve of a centrifugal pump is the relationship between the pressure (p) and the flow (Q) it delivers (for a motor pump at the maximum regulated speed of the combustion engine). The curve determines the capacity of the pump over its working range. Note that at maximum pressure, the flow is zero. Often, a part of the curve is printed in bold. This is the range at which the pump should function to have a high efficiency. The actual working point (the specific pressure and flow at which the pump will function) is determined by the height difference and the head losses in the pipe system that the pump has to overcome (T.B. 2.31; 2.32).
- ***Pump efficiency and power requirements (lower part of the graph)***: Some manufacturers of (electric) centrifugal pumps also provide curves indicating the efficiency (Eta) and the power requirement (P2) of a specific pump. The efficiency is the relation between the power transmitted to the water and the power delivered by the motor. Every pump has its own efficiency curve, which will vary according its flow. The maximum efficiency is where most of the power of the motor is transferred to the water as shown on the curve. The power curve also shows that a centrifugal pump needs the least power when the flow is zero. So if a generator has difficulties to deliver the starting current of an electric centrifugal pump, it's recommended to start it with its gate valve closed (Q = 0, p = max.), because this requires the least power, thus also the least starting current.

Remarks

- Always read the owner's manual before using a pump.
- Motor pumps and generators should never be lowered inside or put directly next to a well to avoid their toxic exhaust gasses accumulating within.
- Dewatering pumps should be stopped and disconnected from their electricity source before people enter the well.
- When a generator is used to supply power to an electric pump, make sure it is earthed.
- Not all surface centrifugal pumps are self-priming; thus not only their pump house has to be filled completely with water before the pump is started, but also their "suction" pipe. In case of doubt if a pump is self-priming, always fill its "suction" pipe with water.
- Some high capacity surface pumps can't "suck up" the water and need to have the water level at the same height as the pump axis, or even above (check the owner's manual).
- Not all centrifugal pumps are capable of pumping turbid water. The possible presence of large quantities of sand or other solid particles in the water may damage the moving parts of the pump.
- The installation of a strainer is compulsory, even for pumps which are specifically manufactured to deal with water that contains solid particles.
- The presence of salty or brackish water may corrode the pump rapidly.
- Some electric pumps have electronic features that start their motor slowly and thus require a lower starting current (consequently also less starting power). It is therefore not necessary to start this kind of pumps with a closed gate valve.
- Be aware that 10 meter Water Column (mWC) is about equal to 100 kPa or 1 bar (with bar and mWC being the unities most commonly used by technicians).

T.B. 2.26 Information required to identify a centrifugal pump

It is very important to determine the correct pump for every situation. In emergencies, the choice will often be restricted because of the limited variety of pump kits. Nevertheless, within the existing range of kits, the pump (characteristics) should correspond as close as possible to the needs. Within chronic emergencies and stabilized situations, a specific pump outside the kit range might have to be chosen according to the design of the water supply system.

Procedure

- Determine the water demand for a certain population and/or a health structure.
- Calculate the desired pump flow (l/s, m³/h) and the number of times it has to start, based on:
 - the daily water demand,
 - the available storage capacity of the reservoirs,
 - and the time available to fill the reservoirs, which is depending on the moment of the day when the population is collecting the water (mainly in the morning and early evening) and/or on the space of time the electrical network or a potential generator is functioning (for electric pumps).
- Collect physical information related to the site: check the diameter and the depth of the hand dug well or borehole, make a sketch with the dimensions of the river bank, the water's edge of the lake or canal (for the determination of the place availability to install a pumping station), verify the altitude (height above the sea level).
- Determine if the yield of the water source can cope with the desired pump flow. If information on the maximum yield of a (tube) well is not available, a pumping test should be performed (T.B. 2.27).
- Collect information on the water characteristics: pH, turbidity, salinity.
- Specify the purpose of the pump: e.g. the pump will be used for water treatment using chemicals as aluminium sulphate or ferric chloride.
- Determine the energy source for pumping: diesel, petrol, electricity, solar.
- Investigate the local knowledge to maintain and repair pumps.
- Determine the exact locations of the water source, the pumping station and the reservoirs, and make a topographic plan that:
 - indicates the vertical distance in meters between the lowest water level and the highest level to which the water has to be pumped, or in other words the **Total Geometric Head (TGH)** (T.B. 2.24). Note that the highest point is not necessarily the storage reservoir. Take also the possible seasonal variations of the water source levels into consideration.
 - gives the total length of the pipe in order to calculate the **Total Head Losses (THL)**. The head losses include the linear head losses (friction of the water passing through the pipe) and the local head losses (e.g. friction of the water passing through valves, bends, strainer) (T.B. 2.31).
- Calculate the **Total Manometric Head (TMH)** (see hereunder).

Total Manometric Head (TMH): total pressure the pump has to deliver (expressed in mWC, kPa or bar)

$$\text{Total Manometric Head (TMH)} = \text{Total Geometric Head (TGH)} + \text{Total Head Losses (THL)}$$

$$\text{Total Geometric Head (TGH)} = \text{Geometric Suction Head (GSH)} + \text{Geometric Delivery Head (GDH)}$$

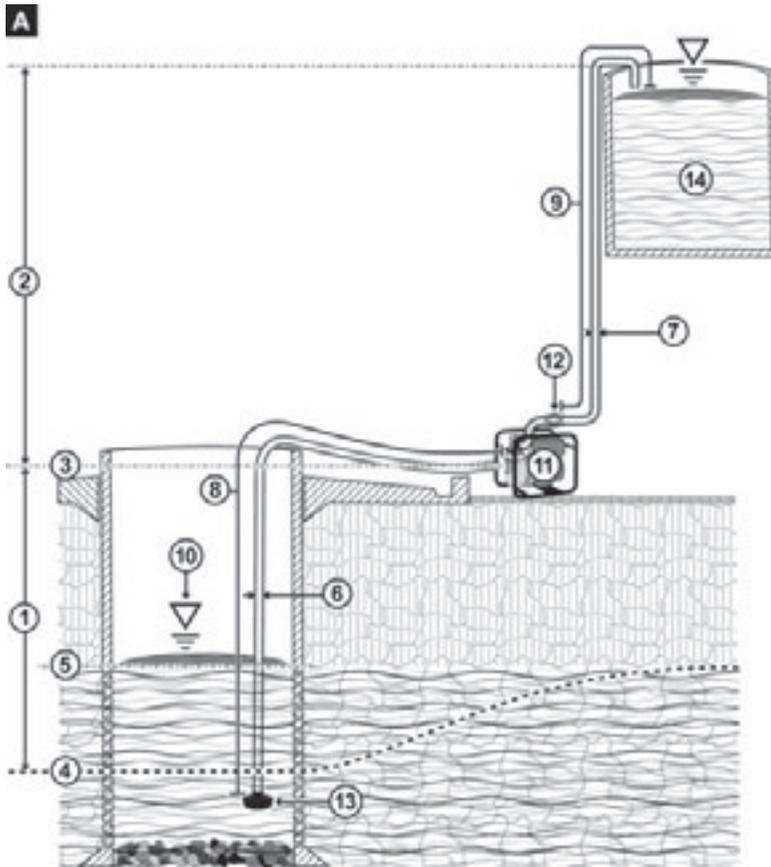
Geometric Suction Head (GSH): from the water resource level to the centre (axle) / inlet of the pump.

Remark: Be aware that for (tube) wells the dynamic water level at the desired flow should be used.

Geometric Delivery Head (GDH): from the pump axle / impellers to the highest point in the delivery system.

Remark: Once the water is pumped over the highest point in the delivery system, siphoning can occur if the actual outlet is at a lower level, which will reduce the Geometric Delivery Head. Still, it is recommended to use the initial GDH to determine the pump in order to be sure that the system will work (assuring that the pump is capable of pushing the water over the highest point). The final result can then only be that the obtained flow is somewhat higher than initially expected.

$$\text{Total Head Losses (THL)} = \text{Suction Head Losses (SHL)} + \text{Delivery Head losses (DHL)}$$



Key

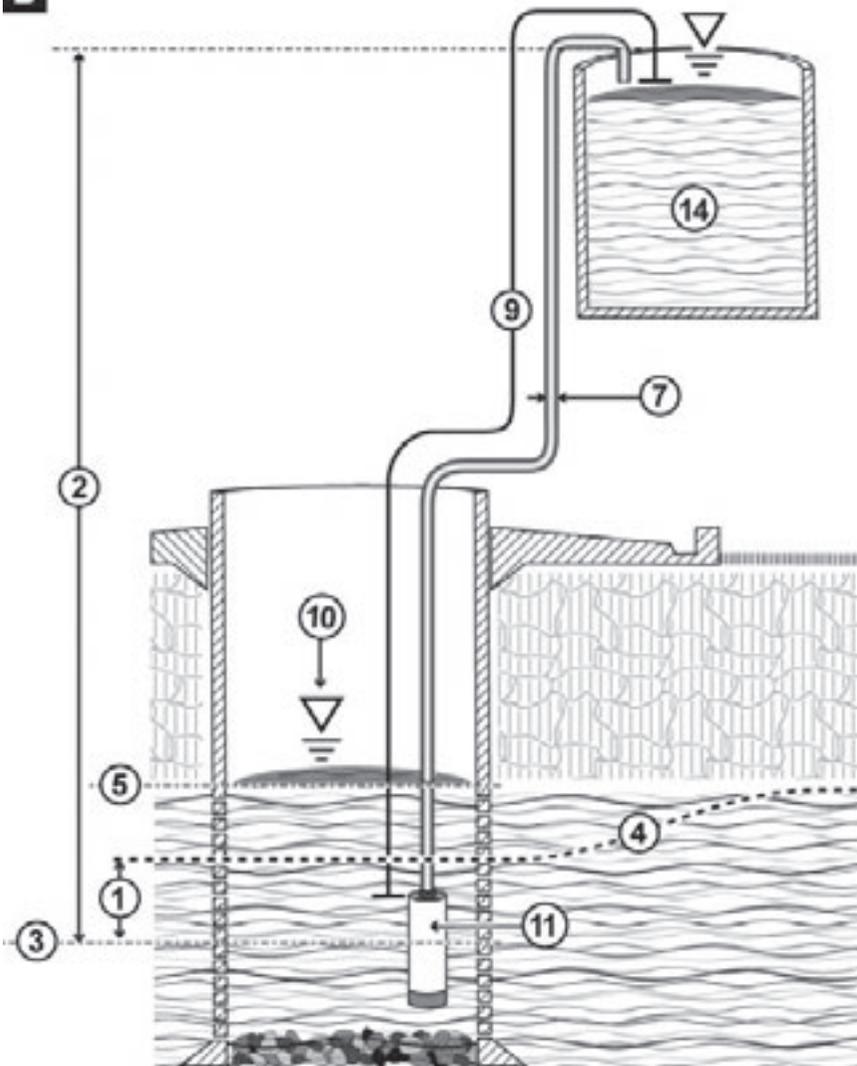
Input

- A. Surface pump
- B. Submersed pump

- 1. Geometric suction head
- 2. Geometric delivery head
- 3. Level of the pump impellor (axis)
- 4. Lowest water level of the source (dynamic)
- 5. Highest water level (static)
- 6. Internal diameter of the suction pipe
- 7. Internal diameter of the delivery pipe
- 8. Length of the suction pipe
- 9. Length of the delivery pipe
- 10. Atmospheric pressure
- 11. Pump
- 12. Non return valve (optional)
- 13. Suction strainer with foot valve
- 14. Storage reservoir

- Measuring equipment (tape measure, level, etc.)
- Sketch and description of the site
- Technical information on pump (characteristics), pipe type (e.g. Heliflex, PE, GI), pipe diameter, couplings, valves, bends, etc.

B



Remarks

- The ease of maintenance and the robustness of the pump; the number of hours the pump has to run or the number of times it has to start per hour; the availability of fuel (what type of fuel) or electricity; the availability of tools, spare parts and maintenance skills; the purchase, running, maintenance and repair costs; these are all factors that should not be underestimated in the choice of a pump (and certainly not for long-term use).
- Electric motors require a higher current (thus more power) to start than to run normally. This should be taken into consideration for the choice of a generator. The required starting current can be reduced for a centrifugal pump by starting it with a closed gate valve at the delivery side. However, this valve has to be opened as soon as the pump has reached its normal regime (only some seconds). Some electric pumps have electronic features that start their motor slowly and thus require a lower starting current (consequently also less starting power). It is therefore not necessary to start this kind of pumps with a closed gate valve.
- Water hammering is a phenomenon that happens when water flowing in a pipe is suddenly stopped (e.g. by quickly closing a ball or a butterfly valve), which results in pressure building up rapidly and the water shooting back in the opposite direction. This leads to several (high) pressure peaks (hammering), and which can end in a damaged water supply system. Only gate valves should be used in pumping systems because their closing time is slow, thus the risk of water hammering reduces drastically (ball and butterfly valves should not be used).
- The suction ability of a surface pump is limited to maximum 7 m at sea level, whatever its motor power. Therefore should the suction height (head) be as small as possible and the length of the suction pipe as short as possible. The suction ability diminishes as the altitude increases (see table hereunder).

Altitude (m)	Loss of suction head (m)
0	0
500	0.60
1000	1.20
1500	1.70
2000	2.20
2500	2.70
3000	3.20
3500	3.60

Motor pumps should never be lowered inside or put directly next to a well to reduce the length of the suction pipe.

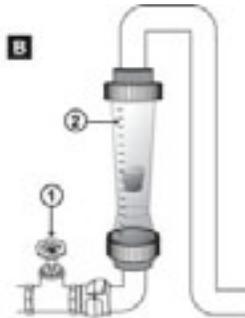
- Not all surface centrifugal pumps are self-priming, thus not only their pump house has to be filled completely with water before the pump is started, but also their “suction” pipe. In case of doubt if the pump is self-priming, always fill the suction pipe with water.
- Some high capacity surface pumps can’t even “suck up” the water and need to have the water level at the same height as the pump axis, or even above (check the owner’s manual). They can only deliver water up to a certain height at a certain flow, which depends on the power and the rotation speed of the motor.
- Not all centrifugal pumps are capable of pumping turbid water. The possible presence of large quantities of sand or other solid particles in the water may damage the moving parts of the pump.
- The presence of salty or brackish water may require a special pump that is less vulnerable to corrosion.
- The height of the water column in a well creates a pressure at the entrance of the submerged pump, thus the Geometric Suction Head (GSH) is negative and needs to be subtracted from the Geometric Delivery Head. This means in practice for submersible and de-watering pumps that the Total Geometric Head can be counted from the dynamic water level until the highest point in the pipe system. Be aware however that some pumps have a maximum pressure (depth) to which they can be submitted. Take also into account that the deeper the pump is lowered inside a well, the longer the delivery pipe has to become, thus the higher the delivery head losses will be.
- The suction head losses for submersible and de-watering pumps are very low because there aren’t any inlet pipes causing friction. However, the friction of the water with the gravel pack and slotted casing of a borehole cannot be neglected (T.B. 2.27).
- Be aware that 10 meter Water Column (mWC) is about equal to 100 kPa or 1 bar (with bar and mWC being the unities most commonly used by technicians).

T.B. 2.27 Determination of the maximum pumping rate of a well

In order to verify if a hand dug well or a tube well (borehole) can cover the water demand, it's important to determine its maximum pumping rate via a pumping test. The maximum pumping rate is also important to identify an appropriate pump for the well. The pumping test consists of recording the evolution of the water drawdown inside the well at increasing flow rates. The dynamic water level related to the maximum pumping rate, together with the depth at which the slotted tube well casing starts also determine at what depth the pump should be installed.

Procedure

- Check the well's logbook for following information: total depth, static water level, dynamic water level at maximum pumping rate and depth where the slotted part of the tube well starts. If the logbook isn't available, all the above mentioned data have to be determined before a pump can be chosen and/or installed. Information on neighbouring wells can provide an estimation of the well depth and the static water level in the area.
- Determine the total depth of the well. This can be done by introducing a disinfected heavy weight (e.g. a stone) on a long rope into the well. Once the weight can't be felt anymore, the bottom is reached. The length of the inserted rope, starting from the ground surface (e.g. the edge of the wellhead / the casing aboveground) until the bottom can be measured, and therefore indicates the total depth of the well.
- Determine the static water level of the well by means of a dipper. A dipper is a probe connected to a long measuring tape that will give a light and/or sound signal when it comes in contact with water. To obtain correct data, the static water level measurement should only be done when the well hasn't been used for at least 24 hours.
- Estimate, in case of a borehole, the depth where the slotted casing starts, based on its total depth and the static water level. A properly designed borehole often has 1 to 3 lengths of slotted casing of 4 to 6 m length each, depending on the extent (thickness) of the underground aquifer. It's important to consider that a correctly designed borehole can never have its static water level lower than the slotted part of the casing.
- Install a motorized centrifugal pump (T.B. 2.25). For shallow wells (static water level less than 6 m deep at sea level), a motor pump can be used. For hand dug wells with a deeper static water level, a dewatering or a submersible pump will have to be used. For deep tube wells a submersible pump will need to be installed, at least 1 m above the slotted casing (T.B. 2.29). A gate valve should be foreseen on the delivery pipe to regulate the pump's flow accurately.
- Start the pump with the gate valve closed, open it slowly and regulate the flow "Q" at 0.5 m³/h by means of the valve. The flow can be determined by measuring the time needed to fill a recipient of known volume (e.g. 20 - 30 l), or a lot easier by an instant flow meter.
- Measure the drawdown "s" (in meter) with the dipper, and follow up until the dynamic water level has stabilized (drawdown < 1 cm/minute) at this specific flow rate. Often a stabilization period of 2 hours is taken, but in acute emergencies, it can be tried to reduce this period.
- Plot the measured figures on a flow (abscissa) / drawdown (ordinate) graph to indicate the working point. A straight line can also be drawn from the graphs zero point (flow = 0, drawdown = 0) across the first flow (Q = 0.5 m³/h) / drawdown (s) working point, representing more or less the linear head losses within the aquifer (as the non-linear head losses will mostly still be low for such a low flow).
- Measure also the turbidity of the well water by means of a turbidity tube (T.B. 2.13). The turbidity should preferably be less than 5 (N)TU, and certainly not above 20 (N)TU.
- Increase the flow to 1 m³/h by opening the gate valve a little more, and whilst monitoring the turbidity, follow the drawdown over the same period as for the flow of 0.5 m³/h.
- Plot the new working point on the graph and interconnect the different working points to form the well curve, representing the linear and non-linear head losses during pumping (as per figure C).
- Keep adding a step of 1 m³/h to the flow rate while measuring the drawdown, and keep on plotting the results on the graph, until the non-linear head losses have become equal to the linear head losses, or until the well curve bends significantly away from the linear head losses line. These phenomena indicate that the critical flow is reached. The critical flow is also reached when the turbidity of the pumped up water starts to rise drastically. In case these phenomena don't occur, the flow rate can be increased until the maximum possible drawdown is reached, meaning that the dynamic water level is still at least 1 m above the pump (or the strainer if a surface pump is used).



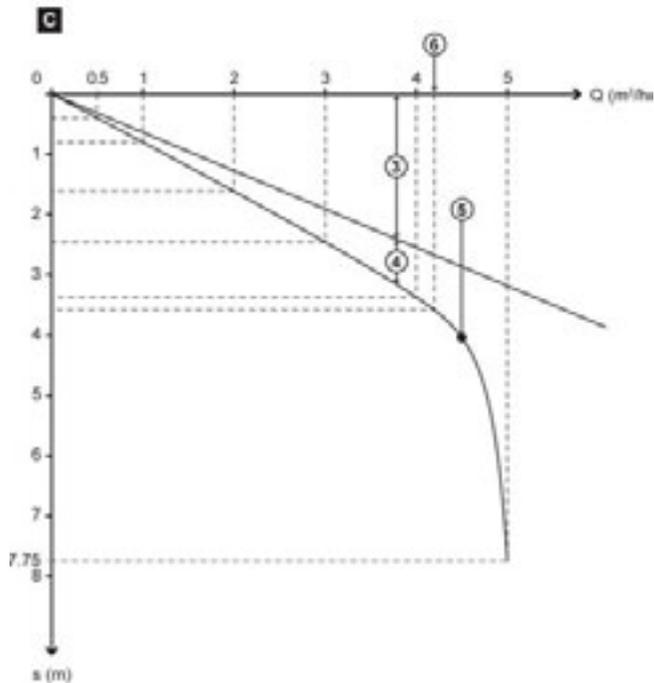
Key

Input

- A. Dipper
- B. Instant flow meter with gate valve
- C. Flow (Q) – drawdown (s) graph

1. Gate valve
2. Instant flow meter (Rota meter)
3. Linear head-losses
4. Non-linear head-losses (turbulence)
5. Critical flow
6. Maximum pumping rate

- Logbook
- Rope and disinfected weight (e.g. spanner)
- Dipper
- Recipient and watch or instant flow meter
- Gate valve
- Pump kit (motor, dewatering or submersible)
- Turbidity tube
- Squared / graph paper, ruler and pen



Interpretation of the results

- When a well is being over-pumped beyond its critical flow, it can result in the well curve bending significantly away from the linear head losses line. This is caused by:
 - important turbulence and thus heavy non-linear head losses within the gravel pack and the slotted casing of a tube well, or
 - the dewatering of a particular productive aquifer.
- In any case, over-pumping should be avoided. This means that the maximum pumping rate should be below the critical flow. In practice, and to play on the safe side, the pump flow rate of the last step before the critical flow is reached, can be considered as the practical maximum pumping rate.
- A serious increase of the turbidity also indicates that the (tube) well is over-pumped. The maximum pumping rate should then be regulated at the flow delivering water with a turbidity of less than 5 (N)TU (maximum 20 (N)TU during acute emergencies).
- In case the critical flow isn't reached, nor the turbidity has risen, the maximum pumping rate should be set at the flow at which the dynamic water level in the well is at least 1 m above the pump / strainer.
- Based on all the results, a logbook with all the available information should be made and archived for future use.

Remarks

- This simplified pumping test provides the possibility to determine rapidly an approximation of the most essential parameters that are needed to exploit safely an existing well. However, the approximations made above do not guarantee any long-term results for the tested well. Other more sophisticated methods exist (e.g. Porchet) and can be found in specific literature (section 2.5 Further reading).
- The following data are important factors for the exploitation of a well:
 - Total depth: in practice the depth from the edge of the wellhead or from the casing aboveground, until the bottom of the well.
 - Static water level: water level before pumping starts (not having been pumped for at least 24 hours).
 - Dynamic water level: water level at a certain pumping rate, preferably at the well's maximum pumping rate (but certainly not above).
 - Maximum pumping rate: the maximum water flow that the well can deliver without having important non-linear head losses, too high turbidity of the water or being sucked dry.
 - Depth where the slotted part of the casing starts: the part where the water enters the tube well.
- Even if the logbook of the well is available, it can be interesting to verify all its data, at least if time permits.
- When determining the total depth of the (tube) well, make sure there aren't any obstacles blocking the free passage of the weight and rope (e.g. a pump).
- An appropriate submersible pump should be installed with its bottom at least 1 m above the slotted casing of the tube well, in order to avoid:
 - erosion of the soil at the level of the pump inlet, and
 - insufficient cooling of the pump motor (T.B. 2.29).
- A dewatering pump or the strainer of a motor pump's "suction" pipe should never be less than 0.5 m away from the bottom of a hand dug well. This is to avoid that settled dirt particles would be pumped up, which would increase the turbidity drastically from the start.
- If the turbidity of the well water is already high before the pumping test starts, it can be an indicator that the well hasn't been designed correctly (e.g. no lining for a hand dug well) and/or developed properly (no slow pumping during prolonged periods). Another possibility is that the well has been over-pumped previously.
- Where water is scarce, avoid wastage during the pumping test by collecting the water in a reservoir.
- The distance in between the well curve and the linear head losses line indicates the non-linear head losses, created by the turbulent flow inside the gravel pack and the slotted casing of the tube well.
- If time is available, it is preferable to increase the flow in steps of 0.5 m³/h, instead of 1 m³/h.
- It is also possible to do a pumping test with a flow in between the two measures where the critical flow appeared, in order to determine the maximum pumping rate more precisely. This is recommended if the "initially obtained" maximum pumping rate is too low in comparison with the desired flow (and thus not covering the water demand).
- After the maximum pumping rate has been determined, it's recommended to pump at this rate for 24 hours, in order to verify the capacity and the stability of the well.

T.B. 2.28 Motor pump kit installation

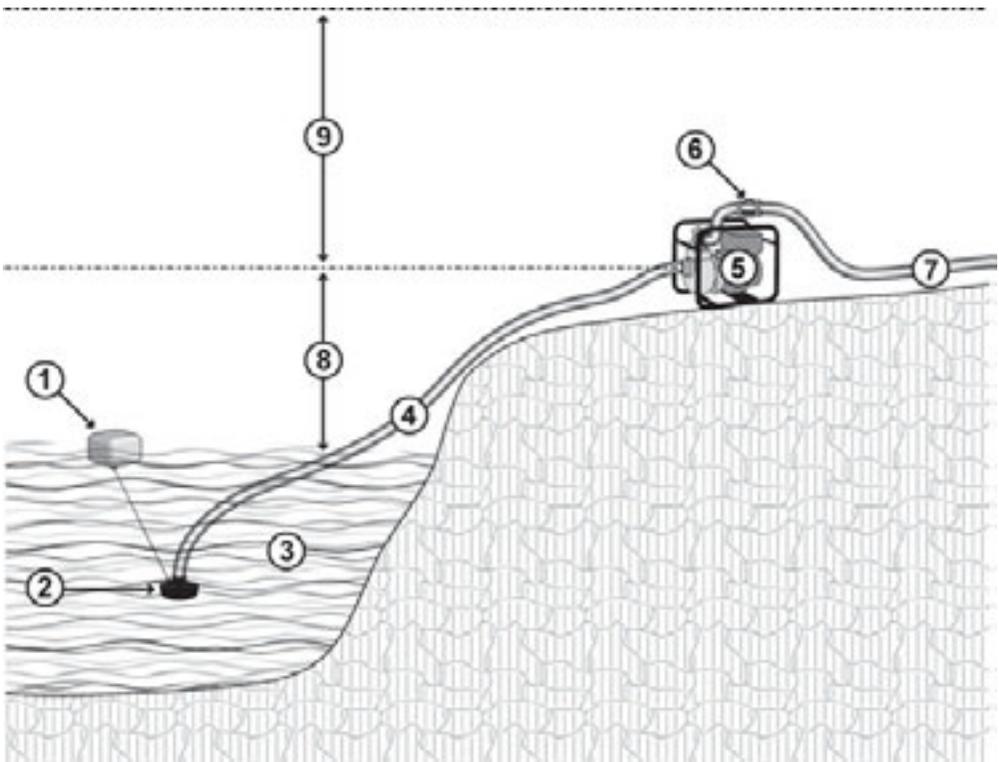
The petrol and diesel motor pump kits are packages designed to provide water in emergency situations. They permit water to be pumped from a water source (e.g. shallow well, river), from or to a water truck or a reservoir. They can also be used for direct water distribution.

Installation and operation

- Choose the pumping site: it should be easily accessible in all seasons and not liable to flooding, particularly where the pump is to be used for filling water trucks.
- Prepare the site so as to install the pump as close to the source as possible, in order to reduce the suction head, but keeping in mind the potential sudden water level differences. Motor pumps should never be lowered inside or put directly next to a well, to avoid their toxic exhaust gasses accumulating within.
- Fit the strainer with foot valve at the lower end of the suction pipe. Attach a float so as to hold the strainer about 0.3 m below the water surface to avoid creating eddies and thus sucking in air and/or floating vegetation, and preferably 0.5 m (at least 0.3 m) above the bottom to avoid sucking in mud.
- Lay the suction pipe on a rising slope (avoid dips if possible), making sure that all the connections are well tightened. An air leak through the connections or a hole in the suction pipe could mean losing the priming of the pump. The total suction head should be limited to 7 m (at sea level). If possible, restrain to one suction pipe as this limits the risk of air leaks and reduces the suction head due to friction losses.
- Lay the delivery pipe up the slope towards the reservoir / tanker filling point and make the connections.
- Check always the oil level of the pump engine before starting. Be aware that new motor pumps are most often delivered without oil in the engine.
- Fill up with fuel. For safety reasons, refuelling should only be done when the engine has cooled down.
- Check regularly the general condition of the motor pump (e.g. the air filter, the spark plug), according to the manufacturer's instructions.
- Fill the pump body with water. Most motor pumps provided under kit form are self-priming, so filling the suction pipe to encourage priming isn't essential. However, for some (high pressure) pumps and older self-priming pumps, and/or when the suction head is high (e.g. nearly 7 m at sea level), it is required to prime the suction pipe as well. In case of doubt, it is always best to fill the suction pipe.
- Start up the pump, following the instructions of the user's manual. Make sure to know how to stop the pump before starting it, to be ready in case something would go wrong.
- Record the pumping periods in the maintenance book to keep a count of the hours the pump has been running, and to plan the engine's maintenance schedule.

Remarks

- Small petrol motor pumps are light, and are therefore also suitable for mobile use (e.g. on a pick-up or a water truck). They are mainly suited for limited pumping times. Small motor pumps are mounted in a frame and are portable by one to two persons. Some models have their 4-stroke engine fitted with a low-oil security system.
- Diesel motor pumps are mainly suitable for fixed installations as they are heavier, which means they have to be carried by at least two persons. They're more suited for long pumping periods.
- The risk of transporting petrol, especially in conflict areas, and the (generally) better availability of diesel should also be taken into account when a choice has to be made between a diesel or a petrol motor pump.
- Some high capacity surface pumps can't even "suck up" the water and need to have the water level at the same height as the pump axis, or even above (check the owner's manual).
- Most motor pump kits are supplied with some lengths of Heliflex pipe, a strainer with non-return valve, a 20 l jerrycan for fuel, engine oil, a funnel, a tool kit with spare parts for normal services, a user's manual and a maintenance logbook. The components of the kit should not be separated. The whole kit should be repacked in its original case if it is to be stored again or sent elsewhere.
- Where the motor pump is to be used for long periods in a fixed position, shelter it from the weather.
- A strainer with non-return foot valve should be installed to exclude large impurities and to keep the suction pipe full of water when the pump is stopped.
- Do not use flat hoses for suction.
- A non-return valve can be installed on the outlet of the pump to protect it against water hammering.
- The recommended conditions for operation and maintenance (e.g. pumping hours, the frequency of oil changes) should be followed to avoid breakdowns, which might interrupt an emergency water supply.



Key

Input

1. Float
2. Strainer with non-return foot valve
3. Water source (e.g. river, well)
4. Heliflex suction pipe
5. Petrol or diesel motor pump
6. Non-return valve (optional)
7. Delivery pipe (Heliflex or flat hose)
8. Geometric suction head
9. Geometric delivery head

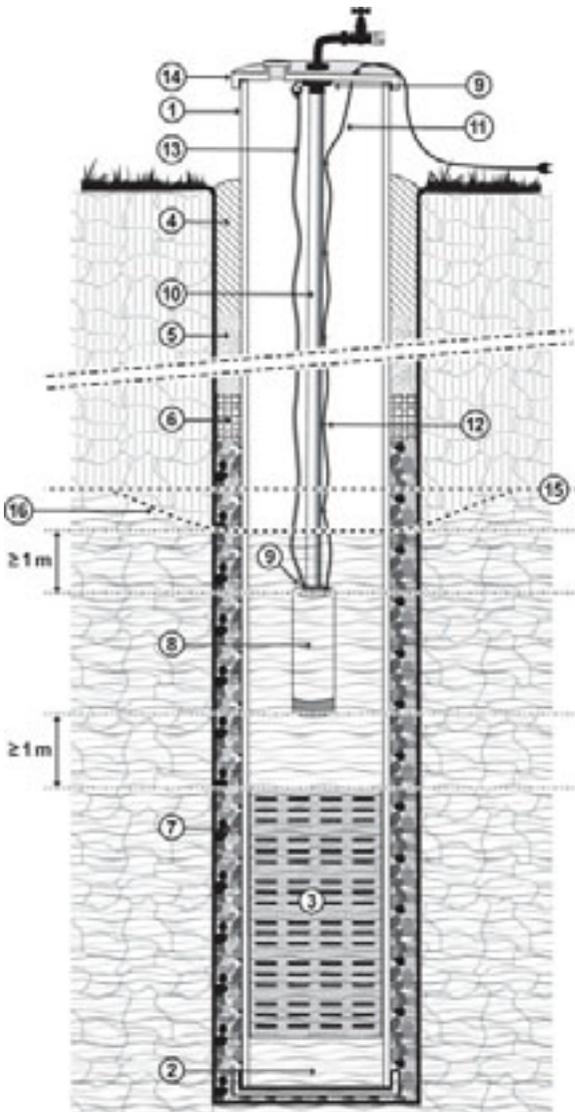
- Shovels and picks for preparing the site
- Fuel (petrol or diesel)
- Complete motor pump kit
- Float and rope
- Reservoirs or water tankers for filling

T.B. 2.29 Submersible pump installation

Submersible pumps are mainly designed to provide water from tube wells (boreholes). With some small modifications, they can also be used in hand dug wells. Although it is also possible with submersible pumps, there are better and cheaper options to pump water from rivers and reservoirs. Submersible pumps should not be used for water containing a lot of particles in suspension ($< 50 \text{ g/m}^3$).

Installation

- Verify the borehole's static water level, the level where the slotted casing starts, its maximum pumping rate and the corresponding dynamic water level. This can be verified by looking in the borehole's logbook and/or by doing a pumping test (T.B. 2.27).
- Determine the water demand / consumption.
- Choose a submersible pump corresponding to the water demand, the amount of time the pump has to run, the electricity supply, the delivery height of the water, while keeping in mind the maximum pumping rate of the borehole (T.B. 2.26).
- Disinfect the borehole with a 1% chlorine mother solution (T.B. 2.03).
- Verify if the wellhead is complete with an elbow, a gate valve and a (fast-)coupling on the outside, and a hook for the security rope on the inside. It should also have a closable opening to introduce a dipper (T.B. 2.27), and a "sealable" opening for the electrical power cable.
- Lay the submersible pump next to the existing borehole on a piece of plastic sheeting and roll off its electrical power cable in a straight line.
- Roll off the raising main next to the electrical power cable, starting from the pump side. The raising main can be a special flat hose or a PE pipe, as long as it has the correct diameter.
- Cut the raising main to the correct length; the pump should be at least 1 m under the dynamic water level at maximum pumping rate, and at least 1 m above the slotted part of the casing. When determining the raising main's length, keep in mind that there might be variations in the water level according to the seasons. As the pump should be hanging directly on the pipe, be also aware that the raising main itself might stretch for up to 3% once it's filled with water.
- Put the appropriate couplings on both extremities of the raising main and tighten them firmly.
- Connect the raising main couplings tightly with Teflon tape to the submersible pump on one side, and to the wellhead on the opposite side.
- Put short lengths of PVC or PE pipe around the electrical power cable at the level of the couplings to avoid it getting damaged by friction.
- Fit the electrical power cable with the provided cable straps (or PVC tape) to (the loops of) the raising main, allowing a little slack (5% by snaking the cable). The electrical power cable should be fixed at every meter of raising main.
- Pass the power cable through the foreseen hole in the wellhead before installing the electrical plug.
- Lay out a rope next to the raising main and electrical power cable. A polypropylene (PP) rope with a minimum diameter of 5 mm is recommended for use in boreholes because it won't rot in this humid environment.
- Cut the rope to the correct length. As the pump won't be hanging on this rope (it's only there as a security in case something would go wrong), it has to be at least 3% longer than the raising main in order for the latter not to kink which would cause serious local head losses; e.g. for 50 m of pipe, the rope should be at least 51.5 m.
- Fix the extremities of the rope to the pump and the wellhead.
- Make sure that the aboveground edge of the casing is cut horizontally because it will be the support of the wellhead.
- Lower the pump with its raising main, cable and rope into the casing whilst cleaning them with water and a cloth soaked in a 0.05% chlorine solution. Take care not to damage any of them. Be aware that the weight will accumulate as the pump with its electrical power cable and the raising main (e.g. 0.5 kg/m) is lowered deeper and deeper in the casing.
- Position the wellhead on top of the casing.
- Connect the water outlet of the wellhead to a reservoir.
- Connect the electrical plug to a power supply and the submersible pump is operational.
- Verify the drawdown when pumping for the first time to avoid that the pump would run dry, and check the turbidity (T.B. 2.13) of the pumped up water (a higher turbidity could indicate that there is over-pumping of the borehole). Adjust the pump's yield with the wellhead's gate valve, if necessary.



Key

- 1 Closed casing
- 2 Closed casing with stopper at bottom
- 3 Slotted casing
- 4 Backfill
- 5 Cement grouting
- 6 Clay (Bentonit) balls
- 7 Gravel pack
- 8 Submersible pump
- 9 Couplings
- 10 Raising main (pipe)
- 11 Electrical power cable
- 12 Cable straps
- 13 Rope (optional)
- 14 Wellhead with accessories
- 15 Static water level
- 16 Dynamic water level (cone)

Input

- Submersible pump with electrical cable
- Wellhead assembly
- Raising main (special flat hose or PE pipe)
- 2 special couplings.
- Cable straps / PVC tape
- Short lengths of PE or PVC hose
- Heavy duty gloves
- Teflon tape
- Knife or hacksaw
- Small screwdriver
- Cloth and 0.05% chlorine solution
- Clean water

Optional

- 2 sets of installation clamps*
- Tripod or rolling wheel (with a car)*

**Items also useful for pump retrieval.*

Remarks

- The relatively easy installation procedures described here are only valid for submersible pumps that have all their protection facilities (e.g. dry run, over- and under voltage, overloading) integrated in the pump itself, thus not needing an external control panel.
- Submersible pumps should preferably be ordered with the electrical power cable already installed, because a faulty installation (e.g. leakages in the electrical isolation) can lead to serious damages and electrocution if a metallic raising main would be used.
- Some aid-agencies provide submersible pumps with all the needed accessories under kit form in order to equip existing boreholes rapidly during acute emergencies. These pumps can be powered with portable generators. Although it is tried to cover a wide flow range, the available variety of submersible pumps in these emergency kits is limited. So for chronic emergencies and stabilized situations, it is strongly recommended to purchase submersible pumps with their accessories (e.g. rising main, wellhead, rope), fully adapted to the delivery height, the desired flow and the corresponding head losses. Remember that the desired flow should not be above the maximum pumping rate of the borehole.
- It is possible to install a small submersible pump with a limited length of flexible raising main manually, but the weight, accumulating as the system is lowered deeper and deeper in the borehole, should not be underestimated. In any case, a minimum of two persons should be located directly at the borehole to lower the pump inside the casing, without the cleaned and disinfected raising main, electrical power cable or rope dragging over its edge. At least a third person should bring the wellhead closer to the borehole as the pump, raising main, electrical power cable and rope are lowered. Other options are to lower the submersible pump and its accessories by means of a rolling wheel (and a car), or a tripod.
- The pump should be lowered or hoisted by the pipe, and the rope and electrical power cable guided. Never pull on the electrical power cable.
- Although often used as raising main, metal pipes are rigid and heavy, and thus more difficult to transport, to install and to retrieve. For the installation and retrieval of such a pump system (e.g. for maintenance or repair purposes), a tripod with pulley-block will be needed. These pipes are also vulnerable to corrosion (at their connections), even if they are made of galvanised iron or epoxy coated steel. Nevertheless, their availability on the spot can be higher than for other materials and they allow the construction of very solid systems.
- Once the submersible pump is installed in the borehole, it's recommended to verify its correct functioning and if its yield doesn't exceed the maximum pumping rate of the tube well. This can be verified through a pumping test (T.B. 2.27), with the help of an instant flow meter and a special device to measure the water level, often called a dipper. In case the maximum pumping rate would be exceeded, the flow of the pump can be reduced by closing the gate valve on top of the wellhead a little.
- For installation in a hand dug well, the submersible pump often needs to be positioned horizontally to stay 1 m under the water surface (dynamic water level) and at least 0.5 m above the bottom of the well. These distances should be respected to avoid the submersible pump respectively going too often into dry-run protection, or "sucking up" settled particles. To avoid suspensible particles to settle on the horizontally positioned pump and therefore reducing its cooling, it needs to be installed within a cooling mantle that is hanging on ropes or standing on long legs.
- Electrical dewatering pumps can also be used within hand dug wells to retrieve potable water, just by being hung up at least 0.5 m above the bottom of the well (similar to figure B in T.B. 2.03). However, attention should be paid not to over-pump the well because dewatering pumps can have a big yield.
- During the first step of hand dug well cleaning, a dewatering pump can be put on the bottom of the well to remove as much sludge as possible (these pumps are capable of dealing with reasonable amounts of turbid water). Afterwards, the pump should be hung at least 0.5 m above the bottom of the well to dewater the hyper-chlorinated water of the disinfection process (T.B. 2.03). During human activities inside the well, the dewatering pump should be stopped and disconnected from the electricity supply to avoid electrocution.

T.B. 2.30 Pipes for potable water supply

There are several types of pipes on the market, all with different advantages and inconveniences. The lay-flat (fireman's) hoses and the spiralled (Heliflex) pipes are often used by aid-agencies, because they are part of the emergency kits. Other common pipe types are made of polyethylene, PVC and galvanised iron.

Classification of pipes

Lay-flat hoses

Lay-flat hoses (fireman's hoses) are commonly available in emergency kits in rolls of up to 50 m and diameters of 2 or 3" (Nominal Diameter ND 50 or ND 80). Being collapsible when not in use, lay-flat hoses can be rolled up in relatively small volumes, which eases their transportation. However, lay-flat hoses cannot be used at the suction side of a pump, they cannot be buried as such in the ground and they tend to kink when changing direction, causing a lot of local head losses (T.B. 2.31). The connections to pumps, tanks or to each other are often made with fast couplings. They usually have a pressure resistance equal or higher than spiralled pipes.

Spiralled pipes

Spiralled pipes (Heliflex pipes) can be used at the suction and the delivery sides of a pump. Spiralled pipes that are usually found in emergency kits have a diameter of 2 or 3"; (ND 50 or ND 80). They usually have a pressure resistance of up to 6 bar. Because they are flexible, some coils of spiralled pipes are often delivered with emergency water tanks and pump kits, permitting the rapid installation of short pipelines. Because of the used couplings and the corresponding high local head losses, Heliflex pipes are often only installed on short distances. Due to their spiral reinforcement, these pipes can also be buried.

Polyethylene (PE) pipe

Especially the smaller diameter PE pipes are flexible. At diameters of up to 75 mm, PE pipes are often sold in coils of tens of meters. PE pipes are easy and fast to install, which explains why they are more and more used in emergencies. The common method for joining PE pipes is through welding, but mechanical couplings are often used as well for small diameter pipes. There are several commercial welding techniques available, from which butt and electro fusion are probably the most common. Both techniques will require a generator. The butt fusion technique uses a welding machine that melts both pipe butts, usually by a hot plate, and then pushes them together to form a watertight joint. The electro fusion technique is probably more easy to use, especially for repairs. It involves a sleeve into which the two pipe ends slide and fuse together once the fitting is connected to the generator. Fusion indicators are commonly designed into the fittings. When sufficient melt pressure has been generated, the indicator will protrude. A welding machine is only worth obtaining if several kilometres of PE pipes have to be installed. Although it is strongly recommended to bury PE pipes, they have already been installed aboveground for relatively long periods during emergencies.

Poly Vinyl Chloride (PVC) pipes

PVC pipes are far less flexible than PE pipes. PVC pipes are commonly available in lengths of 4 to 6 m with push fit insertion joints (collars) or joints that require solvent cement (PVC glue). After both pipe ends have been degreased, the PVC glue can be applied in a longitudinal way on both joints to form a watertight seal once the pipes are pushed into each other. Both glue and degreaser are IATA regulated and cannot be air transported without special authorisations and precautions. Note that not all PVC glue can resist the high pressures that are sometimes reached in potable water supply systems. This should be taken into account when this product is bought locally. PVC pipes should always be protected against direct sunlight.

Galvanised Iron (GI) pipes

Galvanised iron pipes are commonly available in lengths of 4 to 6 m and diameters of up to 4" (100 mm). It is advised to use GI pipes only in special occasions because they are heavy and often expensive. GI pipes can be used for area's where the pipeline:

- cannot be buried,
- is exposed to damage risks (like at rocky area's or at tapstands),
- passes sections with very high pressures (> 16 bar),
- crosses a stream or a road, or is installed inside buildings.

GI pipes are screwed together through a socket or unions. When sockets are used, one has to make the joint watertight by wrapping PTFE (Teflon) tape or hemp with paste around the thread in a clockwise direction before screwing the pipe together. In most countries, pipe-threading sets can be found on the local market (feasible to thread diameters up to 1.5" manually).

Remarks

- To choose the right pipe type, one has to take several factors into consideration such as; the context (emergency or stabilized situation), the volume for storage and transport purposes, the local availability, the quality, the purchase and transport costs, the soil or environmental conditions, the nominal pressure that might occur in the pipes, the easiness to install and to dismantle, the head losses (T.B. 2.31), the available diameters. For long-term systems, it can be worthwhile to test the quality of plastic pipes (PE and PVC). Contact your technical referent if you want to have a test done in Europe to verify if the plastic pipe complies with the standards for food quality, pressure resistance and aging.
- All pipes do have a pressure rating, often expressed in PN (Pression Nominale / Nominal Pressure). The maximum nominal pressure should normally be mentioned on the plastic pipes. A rating PN 6 means that the pipe can resist a nominal pressure of up to 6 bar, and should not be exposed to higher pressures as it risks to burst (certainly over time). The pressures will need to be calculated in order to choose the right kind of pipe (T.B. 2.31; 2.32).
- The sizes of PE and PVC pipes are specified in terms of nominal outside diameter (OD), not by the internal diameter. The inner diameter of plastic pipes depends on the nominal pressure they can sustain: the higher the pressure, the thicker the pipe wall, the smaller the inner diameter. Typical pressure ratings for plastic pipes are PN 4, PN 6, PN 10 and PN 16. In case pressures above 16 bar can occur inside the pipe, other materials like GI will be required.
- To cover longer distances in (acute) emergencies, lay-flat hoses or sometimes PE pipes are installed aboveground because they exist in rolls of tens of meters, which reduces the installation time drastically. In a later stage with correct underground installation (T.B. 2.33), PE is the preferred option over PVC, although they are often more expensive to purchase. PE pipes are faster and easier to install and when there is a rupture of the tube, it will stay localised, whereas a PVC pipe can burst over its entire length.
- In order to keep the pipes safe from damages or deformation, it is important to store, handle and transport them with care.
 - Pipes should never be stored in a pile higher than 1.5 m, in order to avoid accidents and/or damages to the material.
 - PVC pipes with push fit insertion joints (collars) should be stacked in an alternating manner to avoid deformation of the tubes and they must also be stored on a flat surface.
 - In case the pipes are exposed to sunlight, they should be covered completely. Plastic will become brittle over time, even when they have been treated to resist UV-radiation.
 - In cold temperatures, plastic pipes get more brittle and therefore break easier. Specific precaution is needed during handling and transport.
 - Contact with hard surfaces like stones, concrete or metal could damage the plastic and even the threads of GI pipe. It is therefore also important to carry the pipes, and not to drag them along, nor to drop them on the ground.
- Besides the PVC pipes for potable water supply, there are also PVC pipes for rainwater and wastewater drainage. The drainage pipes are not capable to withstand the pressures that are often obtained in potable water supply systems, thus they should never be used for that purpose. On top of that, their plastic often doesn't comply with food quality standards.
- An alternative to welding machines is to weld PE pipes together manually. A metal plate is heated by means of a gas or kerosene torch, to which both PE pipe butts are melted before being pushed manually against each other. The right welding temperature of the metal plate can be verified by means of heat indicating crayons.
- If a lay-flat hose is put horizontally along a slope, the hose might roll towards the bottom of the slope once it is filled. This can be avoided by putting the hose in a shallow (open) trench. If a lay-flat hose is put vertically on a slope, the filled hose might snake into a zigzag shape.
- Special lay-flat hoses exist to install submersible pumps into boreholes (T.B. 2.29). Their extreme high tension strength and special couplings resist the heavy weight of the water column and pump hanging directly on the hose. Such an installation should never be made with the normal fireman's hoses that can be found in the emergency kits.

T.B. 2.31 Head losses

When water flows through a pipe, it will encounter a certain resistance due to friction in between the water molecules themselves, and with the pipe wall. When a pipe, lying on a single slope and closed at its lower end is completely filled with water, an increasing pressure can be measured in the pipe towards its lowest part. When the water is allowed to flow, the pressure within the pipe will accumulatively diminish towards its lower part. These pressure losses, due to accumulative friction losses inside the pipe, are called head losses. For simple and rather straight pipelines (e.g. a short connection from a spring catchment, a tap-stand connected to a reservoir), the head losses can be determined with flow nomographs or tables.

Principle

On a pipeline, two types of head losses are to be found:

- The linear head losses, due to the friction of water passing in the pipe.
- The local head losses, caused by the friction of water passing through accessories such as valves (even when completely open), bends, Tee-pieces, connections.

The head losses are most often expressed in meter Water Column (mWC) per 100 m of pipe length or percentage; a head loss of 1% corresponds to 1 mWC (0.1 bar) per 100 m of pipe length.

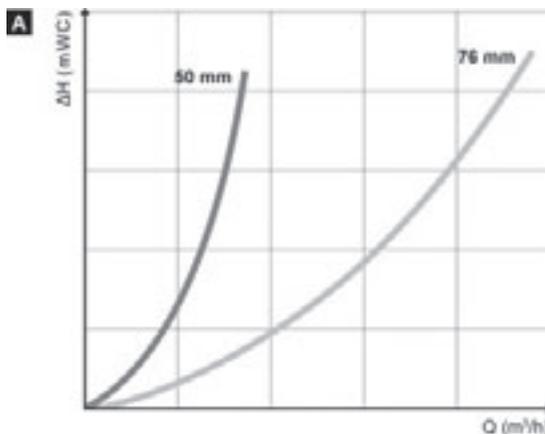
Linear head losses

The linear head losses (ΔH) depend on several factors (represented on the nomograph), which are all interrelated:

- The inner diameter (d) of the pipe (mm).
- The flow (Q) through the pipe (l/s).
- The velocity (v) of the water within the pipe (m/s): it depends on the flow and the inner pipe diameter.
- The roughness of the pipe: it depends on the material; e.g. PE, PVC, GI.
- The length of the pipe.

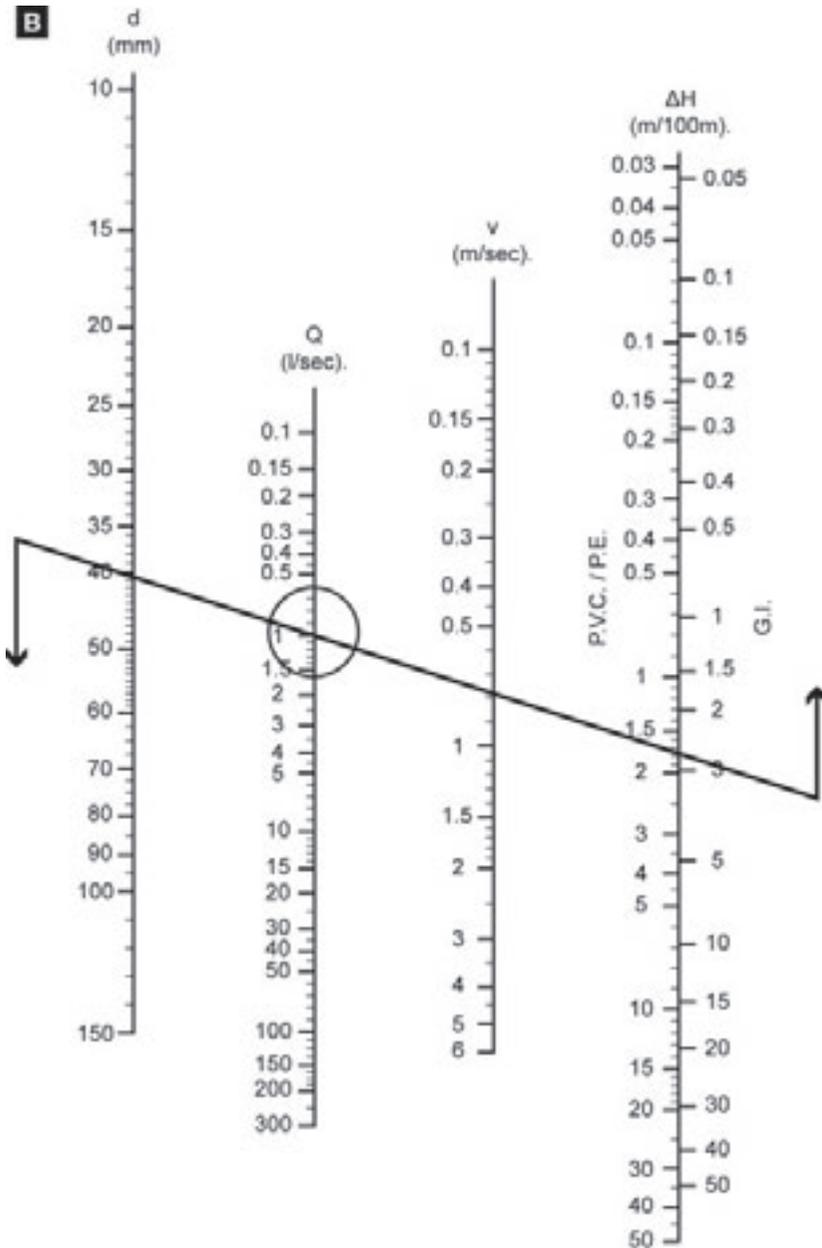
The interrelationship is as follows:

- For a constant flow, same length and roughness of the pipe, the smaller the diameter, the higher the velocity in the pipe and thus the higher the head losses will be (as per figure A).
- For a same diameter, length and roughness of the pipe, the more the flow increases, the higher the velocity in the pipe and thus the higher the head losses will be (as per figure A).
- For a constant flow, same diameter and length, the rougher the pipe, the higher the head losses will be.
- For a constant flow, same diameter and roughness, the longer the pipe, the higher the accumulated head losses will be.



Key

- A. Flow (Q) - head loss (ΔH) graph
- B. Nomograph (adapted from T.D. Jordan)



Use of the Nomograph

When the information of two factors is known, their figures can be plotted on their respective column on the nomograph. By connecting these plotted figures by a straight line over the whole width of the nomograph, the other factors can be directly read or simply calculated.

Some examples:

- If the inner diameter of the pipe and the desired flow are known, the velocity of the water in the pipe and the linear head losses per 100 m pipe length (depending on the material of the pipe) can directly be read. To know the real linear head losses, its figure just has to be multiplied by the real pipe length (taking into account the multiplying factor 100).
- If the maximal potential linear head losses are calculated (depending on the available height difference; T.B. 2.24) and the inner pipe diameter is known, it's possible to read the maximal potential flow passing through the pipe (taking into account the complete pipe length).
- If the desired flow is known and the maximal potential linear head losses are calculated, it's possible to read immediately the needed minimum inner pipe diameter.

Local head losses

To calculate the local head losses, tables exist which indicate for all kinds of accessories the frictional head loss factor to be used in the calculations. However, for simple pipelines with a reasonable length (e.g. some hundreds of meters) and few accessories, the local head losses are often estimated as 15 % of the linear head losses. This estimation isn't valid of course for (rather) complicated pipelines and networks; for instance inside buildings where there are a lot of bends, valves and T-pieces. In case of doubt, contact your technical referent for more information.

Total head losses

Total head losses = linear head losses + all local head losses (mWC)

Often simplified: **Total head losses = linear head losses x 1.15 (mWC)**

Remarks

- The factors influencing the linear head losses will be determined themselves by other aspects:
 - Inner pipe diameter: its choice is restricted by the limited availability of different pipe diameters.
 - Flow: depends on the water demand and the time wanted / available to get it to the beneficiaries.
 - Roughness: depends on the material of the available pipes.
 - Pipe length: depends on local topography.
- The diameter mentioned on the nomograph is the inner diameter. Take this certainly into account for plastic pipes because their outer diameter is standardised in size, whilst their resistance to pressure depends on their wall thickness, and therefore has an influence on their inner diameter. For instance, the inner diameter of a PN 16 pipe is smaller than the inner diameter of a PN 6 pipe of the same external diameter (T.B. 2.30).
- The water velocity is important:
 - A velocity less than 0.7 m/s might result in particles settling inside the pipe, eventually clogging it.
 - A velocity higher than 3.0 m/s might result in particles eroding the pipe, and the risk of serious water hammering increases (T.B. 2.26).
- The linear head losses for PVC and PE pipes are similar.
- For a gravity flow system, the total head losses, expressed in mWC, can never be higher than the height difference in between the water source and the outlet.
- Similar head losses are present when water is moved upwards by means of a pump. When a pump is to be chosen (T.B. 2.25; 2.26; 2.28), these head losses expressed in mWC have to be added to the real height difference that the pump has to overcome (initially the height in between the water surface and the highest point in the water system).
- It is very difficult, if not impossible to estimate the head losses for Heliflex pipes and lay-flat hoses. Some Heliflex pipes have a high "roughness" due to the spiral that is also noticeable on its inside. When several Heliflex pipes are connected to each other, their double fast-couplings, present every so many meters (e.g. 6 - 8 m), will create a lot of local head losses as well. Lay-flat hoses might be quite rough on the inside as well, and they kink very easily (already at the slightest change of direction), thus creating a lot of unpredictable local head losses.

T.B. 2.32 Calculation of a simple pipeline

The calculation of big water supply systems can be very complicated and should be left to specialists, who are often using specific computer software. However, it is possible with simple means to calculate uncomplicated and relatively short pipelines (maximum a couple of kilometres). This kind of calculation requires a proper topographic survey, knowledge about head losses and the use of a nomograph. It is always recommended to have a (specialised) colleague verifying the obtained results.

Procedure

- Perform a basic topographic survey (T.B. 2.24).
 - Determine the total length of the (future) pipeline.
 - Determine the height difference between the outlet of the spring / reservoir and the end tap(stand) / valve (indicated as H_2 in the figure).
 - Determine the maximum pressure that potentially will be applied on the pipes. This maximum pressure is exercised at the lowest point of the gravity flow system when the water isn't moving (all taps / valves closed). Be aware that the lowest point of the system does not necessarily mean the end tap / valve. Thus the maximum pressure in the system is determined by the height difference in between the outlet of the spring or the highest water level in the reservoir and the lowest point of the pipeline (indicated as H_1 in the figure). So the maximum pressure in the pipeline is expressed in meter Water Column (mWC), or bar (if divided by 10).
- Shortlist amongst all the available pipes the types that will resist the maximum pressure (e.g. PE, PVC, GI; T.B. 2.31).
- Choose a specific pipe within this shortlist, and measure its inner diameter (mm). The choice should be based on aspects like costs, availability, transport problems, roughness, food grade quality.
- Determine the flow that needs to pass through the pipeline (converted into l/s), depending on the amount of water (water demand) that needs to be transported over a desired or available time frame.
- Plot both the inner diameter and the flow figures on the nomograph (T.B. 2.30). It's recommended to do this on a copy of the nomograph.
- Interconnect both plotted points with a ruler and draw the line over the whole width of the nomograph.
- Read the velocity of the water. The velocity should preferably be in between 0.7 and 3 m/s.
- Read the head loss in mWC per 100 m of pipe length, depending on the pipe's material (related to the roughness of PVC / PE or GI).
- Calculate the total linear head losses according to the total length of the pipe and add the estimated 15% of local head losses to obtain finally the total head losses in mWC.
- Compare the total head losses in mWC with the total available pressure at the outlet (height difference H_2 in between the water outlet of the spring / reservoir and the tap / valve). When the total head losses are deducted from the total available pressure, there still should be a positive pressure to overcome the local head losses of the tap / valve (minimum 1.2 m and up to 7 m for some tap models).
- Restart the exercise using a decreased flow and/or an increased pipe diameter in case the above mentioned positive pressure isn't reached (or even be negative). The exercise on the determination of the head losses will have to be repeated until an acceptable result is found.

Example

The design of this simple gravity flow water supply system has its reservoir centralised nearby the source, but the distribution takes place at a certain distance. The shortest distance between both is through a small valley. The water demand can be satisfied with one tapstand.

- The topographic survey has been done and provides following information:
 - Length in between the source and the taps, following the valley (total pipe length): $L = 400$ m.
 - Height difference between highest reservoir level and lowest point in the valley: $H_1 = 35$ m.
 - Height difference between outlet of reservoir and taps: $H_2 = 6$ m (available pressure of 6 mWC).
- Technical information regarding the available material:
 - Available PE pipe: PN 6.
 - Inner diameter of the PE pipe PN 6: 50 mm.
 - Head loss in the taps of the available tapstand is 1.6 m at ideal flow of 0.225 l/s per tap.

■ Results of the calculation:

PN 6 pipe (max. 6 bar or 60 m pressure) will withstand the maximum pressure (35 m height or 3.5 bar) at the bottom of the system when all the taps are closed, so it can be used.

Desired ideal flow: 0.225 l/s per tap. For the available tapstand with six taps:

$0.225 \times 6 = 1.35$ l/s when all the taps are open at the same time.

→ The nomograph indicates a head loss of about 1 mWC per 100 m pipe length and the velocity is just at the limit to avoid sedimentation in the pipe (0.7 m/s).

→ For the total pipe length of 400 m, the total linear head loss equals 4 m (1 mWC/100 m x 400 m).

Total head losses = 4 m + 15% local head losses = 4.6 m.

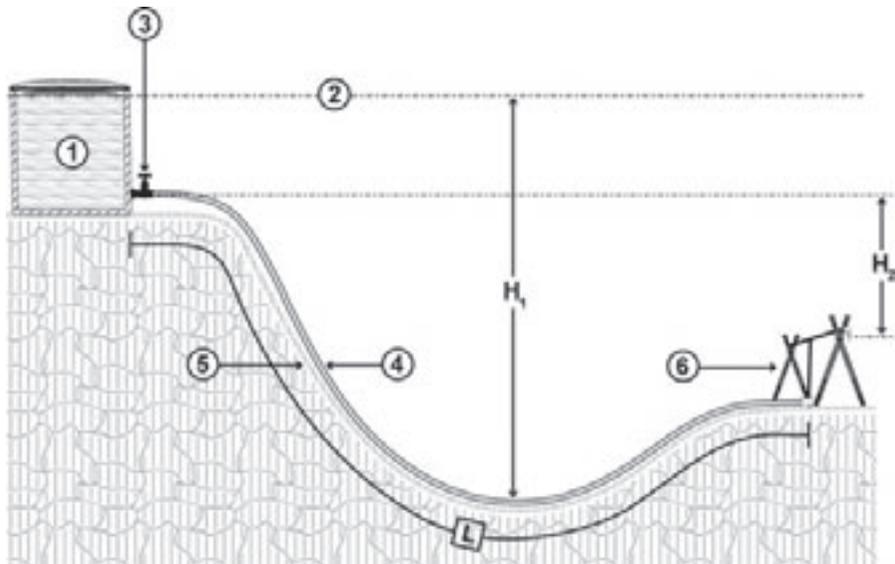
→ 6m available pressure - 4.6 m head losses = 1.4 m pressure left over to overcome the tap head losses.

1.4 m pressure left over - 1.6 m pressure used to overcome tap head losses at this flow = -0.2 m;

the residual head at the outlet of the taps can never be lower than 0 m.

■ Conclusion: the system will work, but at a slightly lower flow than was expected (about 10 l/min per tap).

The velocity in the pipe will also drop below 0.7 m, thus there is a risk of sedimentation within the tube. In case the wanted flow of 1.35 l/s is essential, the simplest solution would be to lower the tapstand by minimum 0.2 m (if the recipients of the beneficiaries would still fit underneath).



Key

Input

1. Reservoir	-Topographic study
2. Highest water level in the reservoir	-Nomograph
3. Outlet of the reservoir	-Calculator
4. Pipeline	-Ruler
5. Topography of the area	-Pen
6. Tapstand	

H_1 : height difference in between the highest level in the reservoir and the lowest point in the valley

H_2 : Height difference in between the outlet of the reservoir and the taps

L: Total length of the pipeline

Remarks

- The above mentioned maximum pressure in the pipe is not considering potential water hammering (T.B. 2.26), which is caused when the water flow is suddenly stopped by closing a ball valve for instance or by an accidental immediate blockage of the pipe. Water hammering, which are enormous pressure shocks, can cause serious damages to the system and even personal injuries, thus one should try to avoid it at all times.
- For plastic pipes, the maximum admissible nominal pressure is often mentioned on the pipe itself; e.g. PN 6 means it can resist to a maximal nominal pressure of 6 bar (T.B. 2.30).
- The choice in pipe diameters is often determined by the availability on the market.
- The diameter mentioned on the nomograph is the inner diameter. Take this certainly into account for plastic pipes because their outer diameter is standardised in size, whilst their wall thickness depends on their resistance to pressure, and therefore has an influence on their inner diameter. For instance, the inner diameter of a PN 16 pipe is smaller than the inner diameter of a PN 6 pipe of the same external diameter (T.B. 2.30).
- The water velocity is important:
 - A velocity less than 0.7 m/s might result in particles settling inside the pipe, eventually clogging it.
 - A velocity higher than 3.0 m/s might result in the particles eroding the pipe, and the risk of serious water hammering increases.
- The height difference H_2 to determine the available pressure at the end tap, should normally be measured in between the water level of the spring / reservoir and the tap. As the water level of a reservoir can vary over time (getting empty, being refilled), it's careful to keep the tank's outlet as a reference because this doesn't (really) change in height and it reflects the minimum pressure available.
- For gravity flow systems, the total head losses in mWC can never be higher than the height difference H_2 in between the water source and the final outlet (e.g. tap). In case the calculated total head losses (in mWC) are higher than the available height difference (in m), the water supply system will regulate automatically its velocity, and therefore the flow will be lower than expected.
- Similar head losses are present when water is moved upwards by means of a pump. When a pump is to be chosen (T.B. 2.25; 2.26; 2.28), these head losses expressed in mWC have to be added to the real height difference that the pump has to overcome (initially the height in between the water surface and the highest point in the water system).
- The maximum pressure resistance of pipes for motorised pump systems should be more than the maximum pressure the pump can deliver (as such the pipes can't burst, even with the pipe system closed / blocked and the pump at maximum pressure).

T.B. 2.33 Pipe installation

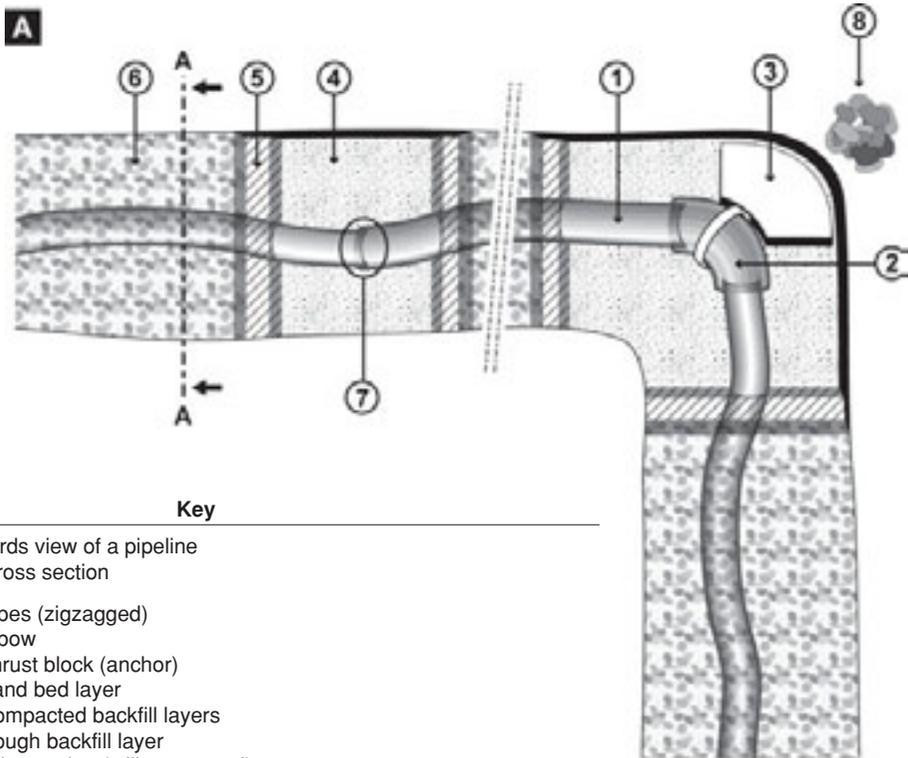
Water is often transported from one place to another through pipes. In acute emergencies, certain pipe types can be installed aboveground to gain time. But to protect the pipes from the environment, the climate and abuse, they should be buried as soon as possible.

Pipe laying

- Mark the future pipeline path clearly with pegs (and strings) to ensure straight lines. For long pipelines, this should normally have been done during or just after the topographic survey (T.B. 2.24). The pipeline should be kept as far away as possible from points where erosion can occur, like landslide areas, gullies and riverbanks.
- Dig the trench with its walls slightly inclined because complete vertical walls tend to collapse easier. The angle will depend on the type of soil. The dug out soil should be put a little away from the trench in order to avoid it would slide back into the ditch. The width at the bottom of the trench should be such that it permits the easy installation of the pipeline. Ideally, a distance of 0.3 m should be foreseen on both sides of the pipe. The strict minimum depth at which a pipe should be buried is 0.5 m, although that the ideal minimum depth is often considered to be around 0.8 m. In reality, the depth of the trench has to be chosen with the aim of protecting the pipeline against:
 - a farm plough in agricultural land: check the depth it might reach.
 - sharp hooves and the weight of heavy animals walking over it.
 - the weight of vehicles at motor road crossings: should be a trench dug of 1.5 m depth or the pipeline protected otherwise.
 - extreme temperatures: pipes can be protected from freezing or heat by laying them deeper in the ground.
 - erosion: the topsoil can erode over the years and the pipes might become exposed. Don't open the trench too far ahead in advance as it can get damaged by erosion, and collect rainwater.
- Remove all rocks and stones from the inclined walls and bottom of the trench, certainly when plastic pipes will be installed because they might get damaged by them.
- Place preferably a sand bed layer of 0.05 m to 0.1 m (recommended) thick at the bottom of the trench, on which the pipeline can rest without any strain. In case the trench is situated in a very humid zone, the bed layer can be made with round pebbles (diameter of 5 to 30 mm) instead of fine sand, in order to drain the groundwater away underneath the pipeline.
- Lay the pipes in a slightly zigzagged manner inside the trench, together with their fittings and accessories (e.g. bends, valves), and connect them in the most appropriate way (T.B. 2.30).
- Do not leave a pipe end open or exposed so as to prevent it from dirt or animals like snakes getting inside. If nothing better is available, simple plugs made of tree branches can be used.
- Anchor all pipes to concrete blocks (thrust blocks) at bends, branch points, valves and at passages of steep slopes, to avoid that the joints would become loose due to the lateral forces where the flowing water changes direction.

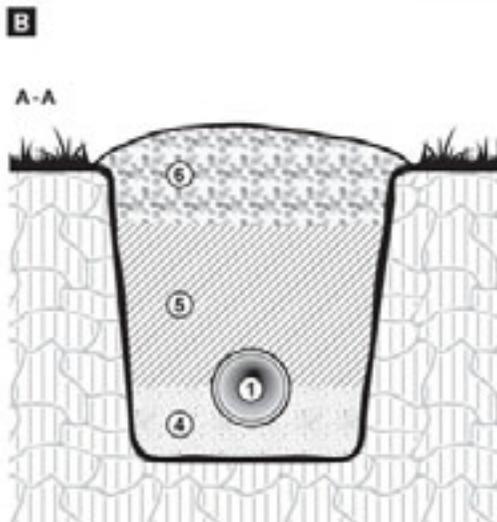
Backfilling

- Backfill the trench as soon as possible to protect the pipe from the sun and vandalism. The backfill material should not contain organic material (such as sticks and bushes). The backfill material should ideally be slightly compacted at every layer of 0.1 m thick.
- Prevent rocks and stones to be dumped on the pipes. Only after the pipe has been covered by around 0.5 m of soil, stones and rocks can be used to backfill.
- Don't cover the joint sections with soil until the pipe has been operated at full pressure and it has been inspected for leaking joints. If the joints are exposed to direct sunlight before they can be inspected, it will be good practice to temporarily cover them (with plastic sheeting for instance). After inspection the joints should be covered.
- Put markers (e.g. piles of stones cemented together) along the pipe line at regular intervals and all important points (e.g. the points where the pipe diameter changes, at direction changes or branch points). Identify the markers by using codes or numbers. If possible, make a sketch of the system, presenting all the available information.
- Plant short rooted vegetation (e.g. grass) on the backfilled trench to stabilise the soil and to protect it against erosion.



Key

- A. Birds view of a pipeline
 B. Cross section
1. Pipes (zigzagged)
 2. Elbow
 3. Thrust block (anchor)
 4. Sand bed layer
 5. Compacted backfill layers
 6. Rough backfill layer
 7. Joint section (still uncovered)
 8. Marker (e.g. pile of stones cemented together)



Remarks

- Prior to the trench excavation and the installation of the pipes, issues related to land and/or water ownership must be taken into consideration and solved (T.B.1.04).
- A flat and levelled storage facility should be prepared nearby the construction area before the pipes arrive on site. The facility should have enough space in order that the piles of pipes don't have to exceed 1.5 m in height. The moment the pipes arrive on site, they should be protected from direct sunlight. If the storage facility isn't a closed shelter, the pipes should be covered. PVC pipes with push fit insertion joints (collars) should be stacked in an alternating manner to avoid deformation of the tubes and they must also be stored on a flat surface. It should also be avoided that the pipes have to stay too long on the site without being installed. The ends of the pipes should be closed to avoid dirt or animals getting in. The plugs have to be removed just before the pipes are installed.
- Care should be taken not to damage the pipes during handling, transport and storage on site. Contact with hard surfaces like stones, concrete or metal could damage the plastic and even the threads of GI pipes. It is therefore important to carry the pipes and not to drag them along, nor to drop them.
- In cold temperatures, plastic pipes get more brittle and therefore break easier. Specific precaution is needed during handling and transport.
- When the pipeline path follows a slope, it is better to start the work downhill and to progress uphill in order that runoff water can evacuate freely and the trench doesn't get flooded.
- In some areas it will be impossible to bury the pipes due to the rocky underground. In these situations, it is preferred to install pipes that can endure shocks and harsh climatic conditions, like GI tubes. All aboveground pipes should be protected at places where heavy animals pass and at vehicle crossings.
- When the trench is less than 1 - 1.5 m deep at motor road crossings, the pipe without any joints should be embedded and covered by 0.2 m of sand. On this sand layer, a reinforced concrete slab of around 0.1 m thick should be poured. Above this concrete slab, the trench can be backfilled normally.
- In some circumstances (road or river crossings), it will be required to install the plastic pipes inside metal (e.g. GI) pipes with a bigger diameter. However, if a leak occurs in the PVC pipes, it will be difficult to localize it. It should also be avoided that dirt, stones or small animals can enter in the openings between the inner and outer pipes. This can be done by wrapping them in plastic sheeting.
- Pipes that are left in the sun, even when already installed, will heat up and expand, but they will contract again when they get buried or when cool water flows through them. To avoid that the contraction might pull the plastic pipes out of their sockets or fittings, they should be installed in a zigzagged manner. The UV-radiation of the sun makes the plastic pipes also brittle over time.
- Anchors and thrust blocks can be made out of simple cement blocks. The pipes and accessories (e.g. bends) can be anchored to the blocks by means of reinforcement iron bars.
- If the length of the path is important, dig the trench over 500 m, install the pipes and backfill the trench before doing the same on the next 500 m. Doing all the procedures over the whole length at once might lead to several problems: e.g. trenches collapsing, damages to uncovered pipes, theft.
- For pipelines of several kilometres in length, it is important to install sludge- and air valves. Sludge valves will need to be opened once in a while to avoid blockages from accumulated dirt / mud particles. Air valves might show their usefulness already from the beginning by removing air-locks when the pipeline is filled for the first time. An air-lock is an air bubble trapped in the pipeline, whose size is such that it interferes with the water flow through the section. They are formed when the pipeline is first constructed or when subsequently drained for maintenance purposes. Anyway, the design and installation of such long pipelines should be left to specialists.
- Before a pipeline can be put into operation, it should be rinsed and disinfected first:
 - Run potable water through the system until no visual dirt comes out anymore, and drain completely.
 - Prepare 10 l of a 1% chlorine mother solution per m³ of pipeline volume (over its whole length).
 - Add all this prepared 1% chlorine solution to a reservoir containing an amount of clean water equal to the pipeline volume and mix well to obtain hyper-chlorinated water.
 - Fill the pipeline completely with this hyper-chlorinated water. The process should be done slowly for the air to be able to escape, and with the end valves closed.
 - Drain the pipeline completely once the contact time of at least 24 hours is passed, and rinse with potable water.
- During an emergency, small air leaks on the suction side of a pump or other small leaks at the distribution pipes can be temporarily repaired with a 1 meter long (x 25 mm) inner tube wrapped tightly around the leak. The leaking pipe or joint should be properly repaired or replaced as soon as possible.

T.B. 2.34 Water trucking

In a large number of emergencies, water trucking is used as a temporary measure to provide water to the beneficiaries. The installation of more sustainable solutions can be time consuming and an urgent need for water often necessitates trucking in the initial stages. However, water trucking is expensive, often difficult to organise and to maintain, thus it should be avoided if feasible or replaced as soon as possible. In most settings, the development of an alternative water supply system will be cheaper in the long run.

Procedure

Water requirements

- Determine the volume of water to be supplied (see example hereunder) and preferably add 10-20% to allow for losses and new arrivals. Losses will vary according to different factors like the quality of equipment (e.g. leaking taps / tankers), the mode of water collection (e.g. jerrycans with cap versus open buckets without lid), the type of delivery point.
- Synchronise where possible the water delivery with the peak demands of the beneficiaries (e.g. early morning and early evening).

Water source

- Select a water source taking into account its yield, its proximity to the delivery point, its access for trucks and its water quality. The loading site of the water source should have enough space to allow easy filling of the trucks and if needed, the installation of a treatment system (e.g. assisted sedimentation; T.B. 2.16) or of a storage infrastructure (e.g. for a low yielding source).

Transport means

- Select the size and type of vehicle, taking into consideration the road conditions (e.g. the load-bearing limit of the road surface, slippery surfaces, steep slopes, tight corners, narrow tracks). Bladders fitted on flatbed trucks or mounted on tractor pulled trailers are a good alternative to water trucks. Solid plastic tanks can also be used, but special attention has to be given to the fact that they will modify the centre of gravity of the truck drastically. Generally, the greater the capacity of the trucks, the more efficient the process is, as long as the road conditions permit the use of big vehicles.
- Calculate the size of the fleet needed by following the steps of the example hereunder. Incorporate a safety factor in the design if the transport fleet is not that reliable, like a back-up vehicle or additional storage capacity at the delivery point.
- Inspect, clean and disinfect with a 0.1% chlorine solution (T.B. 2.20) all the tankers and any associated piping or pumps before use. Rinse them well afterwards with clean disinfected drinking water to remove the chlorine residuals. Avoid tankers that have previously been used to transport oil, fuel or chemicals and opt instead for dairy or brewery type tankers.

Contracting of trucks / drivers

- Hire lorries for water trucking on the basis of either a set time frame (e.g. per month), or on the quantity of water delivered (e.g. per trip of a tanker of known volume). Hiring per quantity of water delivered requires greater monitoring, but motivates the contractor to meet the agreed targets.
- Make contracts and sign them (prior to the start-up of the work), clearly stating the responsibilities of both parties in terms of insurance (in case of accident), vehicle maintenance, fuel and lubricant costs, labour (driver and his helper). In terms of management, it is recommended that the contractor takes on all these responsibilities for a reasonable premium.
- Make sure that the drivers follow the organisational rules and that the vehicles correspond to the regulations of the specific country.

Budget

- Ensure adequate funding for the specified time frame on the basis of a detailed budget, because the running costs of trucking operations are often high.
- Include also more hidden costs like maintenance of loading and delivery points, installation and running costs of storage and treatment facilities, and salaries of watchmen, fleet managers, chlorinators.

Monitoring

- Monitor the quantities delivered and to which water points. A centralised monitoring system will be required in large operations, particularly in situations where different partners are involved.

Example of a Tanker Schedule

Facts

Population	12,000
Min. amount of water needed	15 l/person-day

Calculation of daily requirements

Population x amount/person-day	12,000 x 15 = 180,000 l/day
Estimated wastage 10%	+18,000 l/day
Total	198,000 l/day

Calculation of turn-around time

Time to fill tanker (5 m ³ at 20,000 l/h)	15 min
Journey time from filling till delivery points (17.5 km at 30 km/h on average)	35 min
Time for emptying truck (5 m ³ at 25,000l/h)*	12 min
Return journey time (17.5 km at 30 km/h)	<u>35 min</u>
	97 min
Add 20% for contingencies (e.g. breaks)	19 min
Gross turn-around time	116 min = about 2 hours

The number of tankers can now be determined

$$\text{Number of deliveries per tanker in a day} = \frac{\text{working hours per day}}{\text{gross turnaround time}} = \frac{12}{2} = 6 \text{ rotations}$$

$$\text{Total number of deliveries in a day} = \frac{\text{daily tanked water}}{\text{volume per tanker}} = \frac{198,000}{5,000} = 39.6$$

→ about 40 deliveries/day
→ 7 tankers

$$\text{Number of tankers} = 40 \div 6 = 6.6$$

Summary: A total of 7 trucks with a carrying capacity of 5,000 litres each will be required to make 6 trips per day to supply 15 l/person day to 12,000 people. The selection of 8 tankers, rather than 7, adds a degree of security in case of a breakdown of one of the other tankers.

* Using a pump to offload water from the tanker at the delivery point reduces the turn-around time.

Remarks

- Chlorination within the water truck can save a lot of time because the contact time needed for the disinfectant (T.B. 2.21) can start already during the transport.
- If chlorination of the water has to be done in the trucks, a 1% chlorine mother solution (T.B. 2.20) has to be prepared (only add the supernatant, not the potential calcium deposits). The quantity of chlorine that has to be added per truck should be evaluated by a chlorine jar (modified Horrocks) test (T.B. 2.21). If tankers are metallic, the Free Residual Chlorine (FRC) concentration should be verified at the destination and the chlorine concentration adapted accordingly if needed.
- The selection of water distribution points should be made on the basis that water will be supplied by tankers: ease of tanker access will be the main consideration. Avoid time-consuming offloading procedures like pumping water from tanker to storage tank over extended distances.
- Offloading must be done from the truck to the reservoirs and not directly to the beneficiaries because the latter wastes too much time. It's better that the water truck can leave as soon as possible to fetch another batch of water.
- Efficiency is often an area of weakness in water trucking operations. Attention should be given to reduce the turn-around time and water losses, and to avoid bottlenecks. For example, pumps can be used to reduce the time needed to offload tankers. Having a pump as well as telecommunication means in every truck can thus be considered as advantages.
- If security permits, the trucking should start and stop well beyond the times people collect the water, in order to comply with the peak demands (so potentially have two periods of water trucking of about 6 hours each, around the peak demand periods).
- Given the high costs of water trucking over an extended period, a firm commitment to develop more appropriate water supply solutions for the medium and long-term must be taken. It may involve the development of new water sources and/or transport means (e.g. installation of a pipeline), or the improvement of existing ones.

T.B. 2.35 Emergency water tanks

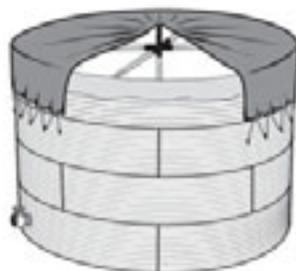
During acute and chronic emergencies, several types of water tanks can be used. Apart from storage, certain tanks can also be used for other purposes like transport or water treatment (e.g. assisted sedimentation). Before ordering a certain type of water tank, one has to consider the most likely use, the size of the tank needed, the time and easiness to set it up.

Most commonly used tanks in emergencies

Type	Capacity m ³	Set up	Use	Remarks
Bladder (pillow tank) Closed tank	0.85 2 5	-Very easy and fast to set up - Mountable on a flatbed truck	- Storage - Chlorination - Transport	- Static or mobile - Difficult to clean
Bladder (pillow tank) Closed tank	15	- Very easy and fast to set up	- Storage - Chlorination	- Static - Difficult to clean
Onion tank Self sustaining open tank with roof	30	-Very easy and fast to set up	- Storage - Chlorination - (Assisted) sedimentation	- Static - Relatively difficult to clean
Liner tank supported by metal frame Open with roof	10 30 60	- Easy and relatively fast to set up	- Storage - Chlorination - (Assisted) sedimentation	- Static - Easy to clean when mounted
Corrugated iron sheet tank with a separate lining Open with roof	11 45 70 95	- Least easy to set up - Bulky transport because of corrugated sheeting	- Storage - Chlorination - (Assisted) sedimentation	- Static - Easy to clean when mounted - Less suited for acute emergency - Longer life expectancy

Remarks

- The permanent available volume of water that needs to be stored to avoid shortages is situation dependent:
 - For a health centre, a storage capacity of 2 days water supply is considered as a minimum.
 - For a refugee or an Internally Displaced Persons camp, a general storage capacity of 5 l/person is recommended as a strict minimum.
- Besides the above mentioned factors, the choice of the type of tank can also depend on other issues like:
 - expected use and local conditions (e.g. climate, security).
 - purchase price.
- Storage tanks must be placed upon a sound foundation. When the water tanks are full, considerable pressure is exerted on the ground. If the construction is not adequately designed and/or the soil at the tank's base becomes saturated with water, there is risk of collapse.
- For the water to be distributed by gravity, the tanks will have to be higher than the taps. This height difference can be reached by using a natural slope or by building platforms. When a natural slope isn't available or there isn't time or material to build a platform rapidly, a hand or motor pump can be connected to the reservoir to assure the water distribution (T.B. 2.36).
- The area around the storage tanks must be fenced and may have to be guarded to prevent abuse and vandalism.

A**B****C****D****Key**

-
- A. Bladder tank
 - B. Onion tank with cover
 - C. Plastic liner tank supported by open metal frame with cover
 - D. Corrugated iron sheet tank with a separate lining and cover
-

T.B. 2.36 Installation of flexible reservoirs

Flexible reservoir kits are designed to supply water rapidly during emergencies. Once the base prepared (e.g. raised platform), the reservoir can be very quickly operational: from a few minutes for a bladder or an onion tank till some hours for a reservoir with a frame.

Installation

- Choose a site for the installation, ensuring that the reservoir will be accessible under all circumstances and at all times to be able to fill it (e.g. by water trucking). A reservoir filled with water is heavy (e.g. about 15 ton for a full 15 m³ bladder) and needs to be installed at a safe location where it can't cause accidents (e.g. a filled reservoir rolling down a slope, or a bladder on top of a non-reinforced flat roof). Discussions with the different stakeholders must also be undertaken when choosing the site.
- Prepare a base to install the tank by:
 - using the natural slope of the terrain or a safe existing construction. This method allows a relatively rapid installation of the reservoir. But the slope should not be too steep and might need to be excavated to have a flat base. The existing construction on the other hand should be strong enough not to collapse under the heavy weight of the filled reservoir.
 - constructing a platform strong enough to withstand the heavy weight of the filled reservoir. All kinds of material can be used to construct a platform: e.g. compacted earth with sloped embankment, oil drums (the drums at the perimeter filled with stones or soil for stability), sand bags, wooden beams and planks, (cemented) boulders, gabions. In case such material would only be available in limited amounts or that it would become too expensive, it's possible to use it only for the outer hull of the platform and fill the inside with stones and/or earth.
 - putting the reservoir straight on the ground without a height difference and supply the tapstands with water by means of a hand pump or a motor pump. This system has the advantage that it can be installed very quickly with a minimum of preparation. When a motor pump is used, the distribution system can easily be extended, but it consumes fuel.

The base for the reservoir should be flat and larger than the surface of the empty tank (a minimum free space of 0.3 m all around the tank should be foreseen). The base should be cleared of all objects that could puncture the tank (e.g. stones, sticks, nails) and if possible, covered with a layer of sand.
- Spread the groundsheet out on the base.
- Put the tank (the liner and the potential frame) on the groundsheet, taking into consideration the direction of its outlet(s). In case of a frame, assemble it and connect the flexible tank liner according to the manufacturer's instructions.
- Verify if the outlet valves of the reservoir are well tightened and adjust if needed (the manufacturers don't always tighten them very well, or haven't even installed them at all). Teflon tape can be used to avoid leaks at this level.
- Organise the distribution point(s) by installing the tapstands (T.B. 2.39). An alternative for very short term distribution is to use the ball valves that are supplied in certain kits.
- Connect the pipe(s) between the tank and the distribution point(s), potentially via a pump.
- Install a drainage system around the reservoir's base and around the distribution point(s) to avoid rapid deterioration of the sites.
- Install a shadow net, or a roof made of local vegetation (e.g. banana leaves) or plastic sheeting over the reservoir to protect it at least against direct sunlight. This helps to avoid that the water in the tank gets warm. It will also protect the plastic liner against UV-irradiation, which renders the material brittle over a prolonged period. For very harsh weather conditions (e.g. freezing temperatures), special protective measures have to be taken. In such cases, contact your technical referent.
- Build a fence to avoid kids playing with or on the (flexible) reservoir. It is also strongly recommended to have an attendant at the reservoir for safety, operation and maintenance.

Key

Input

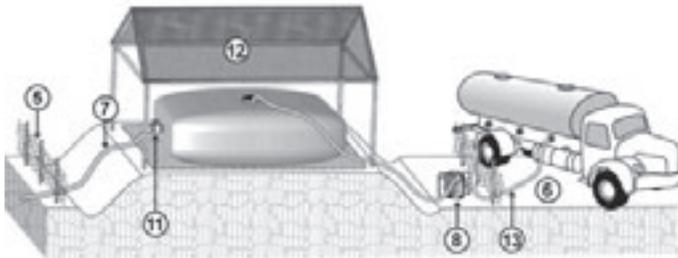
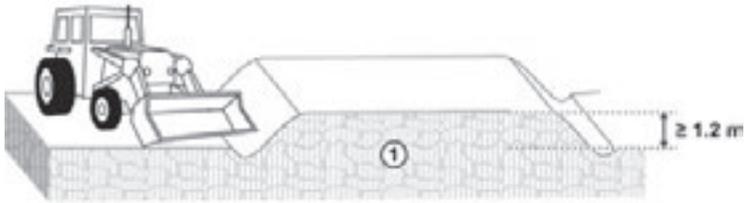
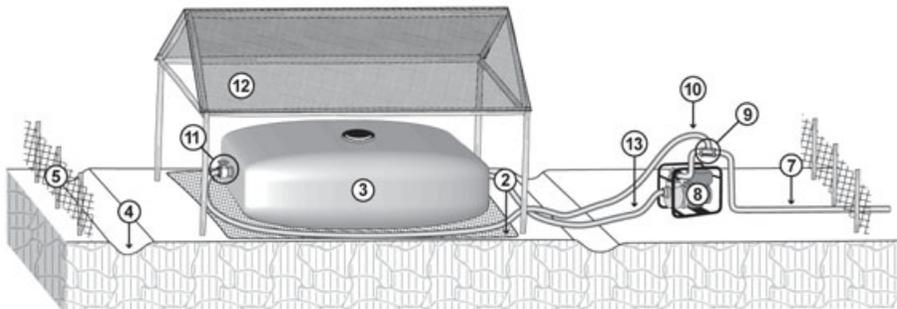
A. Installation on a raised platform

B. Reservoir on the ground with the supply via a motor pump

1. Platform (e.g. earth, drums, timber, natural slope)	- Excavation equipment
2. Groundsheet	- Material to make platform
3. Reservoir	- Fence material
4. Drainage channel	- Reservoir kit with accessories
5. Fence	- Motor pump kit (water supply)
6. (Raised) lorry access	- Hand pump to supply tap-stand
7. Pipeline towards the tapstands	- Tapstands kit
8. Motor pump	- (Water truck to fill the tank)
9. Tee-piece	
10. Recirculation pipe back towards the reservoir	
11. Gate valve	
12. Roof (e.g. shadow netting)	
13. Suction pipe	

Remarks

- In order to avoid abuse of the (flexible) reservoir, it is recommended not to have it too close to the distribution point(s). However, the longer the distance, the higher the head losses in the delivery pipe(s) and the lower the flow (T.B. 2.31) will be. This is certainly important when a platform needs to be built because the higher the head losses, the higher the reservoir needs to be. Also when the water is delivered from the reservoir to the tapstand via a hand pump, the distance should be restricted.
- Bladders can be filled via the central opening or via one of the side connections. In the latter case, the cap of the central opening must be unscrewed and put loosely on top, allowing the air that is trapped inside the reservoir to escape, but without dirt entering. Do not overfill the tank: when water is overflowing via the central opening, the reservoir is full.
- When water is pumped from the reservoir to a tapstand by means of a motor pump, a recirculation system from the pump directly back to the reservoir must be installed (as per figure B). This is to avoid that the pump and the water inside would heat up when all the taps are closed. Failing to have a recirculation system can potentially lead to personal injury (burns) and will eventually break the pump. In cold weather, this recirculation system also reduces the risk of the water starting to freeze in the reservoir and the pipes.
- Do not loose the hook spanners. If they get lost, there are some in the water tool kit.
- When rationing the water, the gate valve(s) of the reservoir can be closed and the knob removed. Be careful not to loose the knob.
- After use, it is essential to clean, disinfect and dry the tank completely before repacking it (T.B. 2.37). Do not fold the tank until it is completely dry (takes 2 - 3 days of drying, at least).
- To repair the reservoir, use the repair module that is included in the kit and follow the instructions carefully.
- Metal construction scaffolding can be used to construct a water tower, permitting the relatively rapid installation of reservoirs on rather high elevations (e.g. 3 m). Only professional scaffolding should be installed on a solid underground (preferably concrete foundation) to avoid the risk of collapse once the reservoir is filled. This solution could be particularly interesting where a centralised water supply system is required (e.g. in a health structure).

A**B**

T.B. 2.37 Cleaning of flexible reservoirs

Reservoirs should regularly be cleaned to remove the bacterial layer (bio-film) and/or the particles that have accumulated inside the tank. Both will lead to a higher chlorine demand and a faster reduction of the Free Residual Chlorine (FRC) concentration. Also when flexible water reservoirs aren't needed anymore, due to the reduction of the activities or due to the replacement by more solid tanks, it is strongly recommended to recuperate them for later use. Of course, the flexible reservoirs should be checked, cleaned, disinfected and dried before they are stored in the warehouse.

Operation

External cleaning of all kinds of flexible reservoirs

- Check the reservoir for leakages or other damages (e.g. faulty connections). Repair them when needed and if it is still possible. The check up for leaks is easiest by filling the reservoir completely with water. In case of holes, fix them with the repair material included in the kit, according to the manufacturer's instructions.
- Put the groundsheet of the reservoir on a big, clean, flat but slightly sloped surface (e.g. tarmac, concrete). Make sure that the sloped surface has a drainage system at its bottom.
- Wet the groundsheet with clean, non-salty water, clean it on both sides with water and liquid soap by means of a soft brush and rinse it to remove all dirt and soap residues. It is possible that some force will have to be used to remove all dirt.
- Put the reservoir (liner) on the cleaned groundsheet.
- Drain all the remaining water out of the reservoir.
- Wet the reservoir with clean, non-salty water, clean it on all outer sides with water and liquid soap by means of a soft brush and rinse it to remove all dirt and soap residues. Before flipping the reservoir over to clean the bottom side in a similar way, it is recommended to rinse the groundsheet again in order to avoid that dirt coming from the bottom of the tank would be transferred to its cleaned side.
- Rinse the complete reservoir and groundsheet thoroughly again with clean, non-salty water.

Internal cleaning of bladder tanks

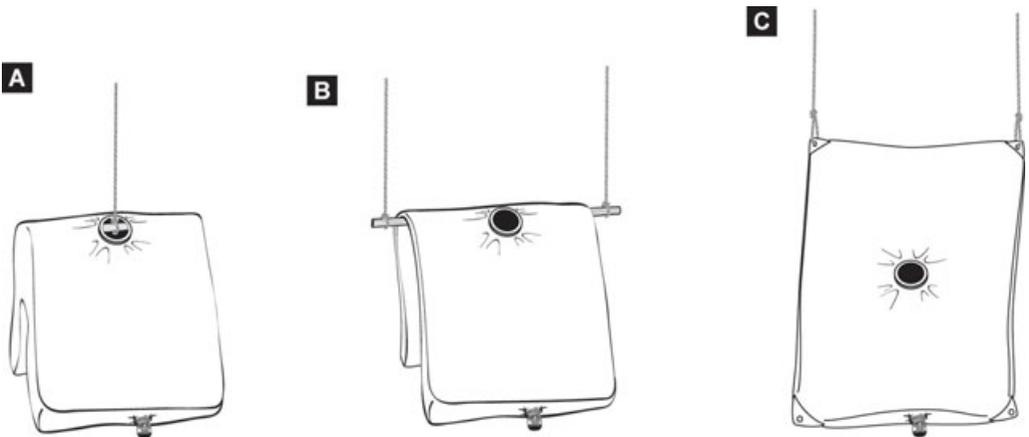
- Move the bladder and its groundsheet to a big, clean and completely flat surface (e.g. tarmac, concrete).
- Once installed and the side opening(s) closed, fill the bladder with some clean, non-salty water in order to get an even thin water layer of 2 - 3 cm thick.
- Rub the upper side of the bladder against its bottom side in order to loosen all the dirt inside. Special attention should be given to the corners of the bladder.
- Empty the bladder via a side opening by lifting the reservoir at the other side.
- Keep repeating these actions until no dirty water comes out of the bladder anymore. When the inside of the bladder would stay dirty (e.g. high presence of algae or a bio-film), a certain amount of 1% chlorine mother solution can be added (e.g. 20 l for a 2 m³ bladder, 40 l for a 5 m³ bladder and 100 l for a 15 m³ bladder; T.B. 2.20) when a new thin layer of clean non-salty water is introduced. This high chlorine concentration should help to remove the organic material.
- Add some 1% chlorine mother solution inside the bladder (10 l for a 2 m³ model, 20 l for a 5 m³ model and 50 l for a 15 m³ model) when a new thin layer of clean non-salty water is introduced, with the intention to disinfect the reservoir. The solution can be drained from the reservoir after at least 30 minutes.
- Rinse the reservoir inside and out for a last time with clean, non-salty and disinfected water, as well as its groundsheet.

Internal cleaning of open tanks

- Turn the reservoir (liner) inside out on its clean groundsheet. For a reservoir with a (corrugated sheet) frame, it's often easier to clean and disinfect the inside of the liner when it is still mounted.
- Wet the inside of the reservoir with clean, non-salty water and clean it with water and liquid soap by means of a soft brush.
- Rinse the reservoir thoroughly with clean, non-salty water until all dirt and soap residues have disappeared.
- Disinfect the inside of the cleaned open reservoirs by means of a clean cloth or sponge soaked in 0.05% chlorine solution (T.B. 2.20). When a sprayer is available, it can be used as an easy alternative to disinfect the reservoirs.
- Rinse the groundsheet and the reservoir (inside and outside) for a last time with clean, non-salty and disinfected water.

Re-packing of reservoirs

- Dry the reservoir properly, preferably in a non-humid environment (e.g. inside a building to avoid that it gets wet by the rain). The drying can be done by hanging the reservoir up without touching the ground, whilst the different surfaces of the plastic liner (bottom and upper sides of a bladder, bottom and vertical sides of an open tank) should stay well separated from each other. When possible, have all the openings open and pointing downwards so the water can drip out easily. In case a compressor is available, blow compressed air into the (bladder) reservoir to dry it.
- Put some talc powder in and on the reservoir in order to absorb the last humidity, once the reservoir seems completely dry.
- Fold the reservoir properly and store it in a solid crate, together with all its accessories. The crate is preferably made out of metal to protect the liner against rats biting holes in it. Make sure that the solid elements of the reservoir can't damage its plastic liner; e.g. the couplings should be covered with some cardboard or with the plastic envelop that sometimes is issued by the manufacturer.



Key

- Drying of a flexible reservoir by hanging it:
- A. on a metallic tube introduced via the central opening
 - B. over an external metallic tube
 - C. on the corner reinforcements

Input

- Big concrete / tarmac surface
- Plenty of clean, non-salty water
- Liquid soap
- Soft brushes (on long stick)
- Chlorine (Chlorination kit)
- Graduated buckets / jerrycans
- Protective clothing (gloves, boots, overall, goggles or face shield)

Remarks

- Make sure that the cleaners wear their appropriate protective gear (an overall, rubber boots, rubber gloves, goggles or a face shield), certainly when they are working with chlorine (as chlorine splatters might cause injuries).
- Salty water cannot be used because it could corrode the valves and leave salt residues on the reservoir and groundsheet.
- Make sure that all openings of the bladder tanks are well closed during its external cleaning to avoid soap getting inside. If some residuals of the soap would stay behind in the bladder, it could give a bad taste to the water when the reservoir would be put in use again.
- The internal cleaning of the 15 m³ bladder can be started by pumping clean, non-salty water across the reservoir. The water should enter via one side opening and leaving via the opposite opening. The flow rate of the pump should be adapted to the evacuation rate at the opposite side (the reservoir should not start to swell up). The pumped water will remove already the first dirt particles from the tank. The pump period shouldn't take too long and can be stopped when the first wave of really dirty water has been evacuated. The same principle can be repeated once more in the opposite direction. The rest of the internal cleaning should be done as described above.
- A soft brush on a stick can sometimes also be helpful to clean the inside of the smaller bladder models. However, a very flat surface is needed to be able to clean it with this method.
- The easiest way of cleaning onion tanks is to clean the outside wall first, turn it upside-down and clean its bottom, then turn it inside out and repeat the same procedure again (first the inside wall that has come on the outside now, then the bottom). In between each step, the reservoir and groundsheet should be well rinsed. This procedure ensures that no spots of the tank will be missed. This principle can also be used for flexible reservoirs with a support frame in case they wouldn't be installed any longer.
- This kind of cleaning is not required after each cycle of assisted batch sedimentation (T.B. 2.16).
- Some brands provide specific features to ease the hanging of the reservoir (e.g. special reinforcements at the corners of bladders, as per figure C; a big internal central ring on some onion tanks). Bladders that don't have these features can be hung over a long smooth metal bar or a bamboo stick and lifted from the ground by means of ropes (as per figure B). A better alternative is to use a smooth metal pipe (+/- 1 m long) that is introduced inside the reservoir through its central opening and then hoisted from the ground (as per figure A). The advantage of this system is that the upper and bottom sides of the reservoir can be separated from each other for better drying. The edges of the pipe should be protected with a cloth to avoid puncturing the liner.
- Make sure that all accessories of the kit are present before starting to repack (e.g. hoses, valves, all the bolts and nuts of reservoirs with a frame). If parts are missing, they should be replaced
- Before taking the used and cleaned reservoirs in use again, rinse their inside with some clean and non-salty water to remove all the talc powder.

T.B. 2.38 Ferrocement tank

The construction of a ferrocement water tank may be considered when planning to make a long-term storage system, like for rainwater harvesting. Its water tightness and strength are directly related to the quality of materials used and the care taken in its construction. The round shape of the ferrocement tank is created by using a removable mould to which wire mesh is attached that will be covered afterwards with a cement coating. It is equally possible to build a framework of reinforcement bars which avoids having to use a mould. The bars are embedded in the cement coating, thus reinforcing the structure.

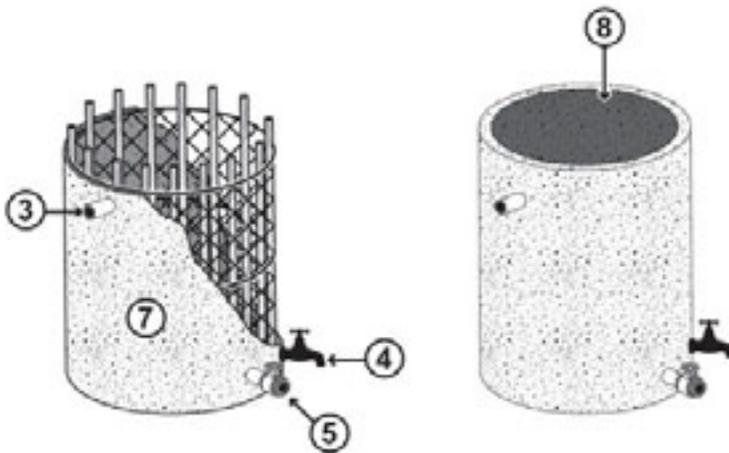
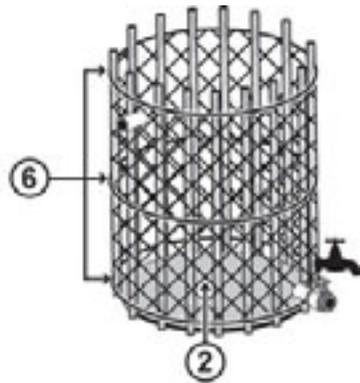
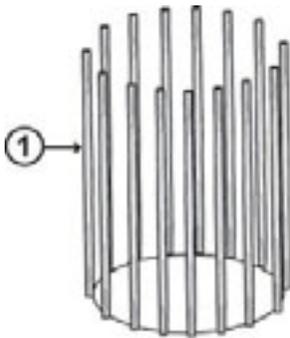
Construction

Technique using wooden stakes (for a tank of 1,500 l)

- Drive stakes vertically into the ground, forming a circle of 1.2 m in diameter. The centres of the stakes should be spaced about 0.2 m from each other, leaving at least 1.5 m of their length aboveground.
- Wind three thicknesses of wire mesh around the circle of stakes. Stretch and flatten the layers of mesh well against each other and fix them to the stakes and to each other with fine wire.
- Reinforce the structure by winding round it three turns of thick wire: at the top, in the middle and at the bottom.
- Push a length of galvanised iron pipe with a valve attached through the mesh near the bottom (for draining), and another one diagonally above with a valve or tap for the outlet. In case water is taken directly from the tank, there should be high enough space in between the ground surface and the tap to be able to put containers underneath. A third pipe for the overflow is fixed near the top of the tank.
- Apply a 10 mm first coat of cement plaster (T.B. 2.05) to the outside. One person should be on the inside to retain the mortar with a float as it is applied. Leave it to harden for 12 to 24 hours, keeping it damp.
- Cut the wires that connect the mesh to the stakes.
- Pull out the stakes and cut off the wires that stick out of the mesh.
- Apply a 10 mm coat of cement plaster to the inside so as to cover the mesh completely. Leave it to harden for 12 to 24 hours, keeping it damp.
- Apply a finishing coat (smooth cement plaster; T.B. 2.05) to the inside and the outside and smooth well.
- Cover the bottom of the tank with wire mesh and curve it up at the corners where the walls meet the bottom.
- Apply a 10 mm layer of cement plaster on the bottom, forming a slope towards the drainpipe.
- Apply a second 10 mm cement plaster coat once the first one has dried, and smooth it well.

Remarks

- The composition of cement plaster is described in T.B. 2.05. To simplify, it can also be composed of 1 part cement to 2 parts of clean, sieved sand.
- The final thickness of the tank walls should be 30 to 40 mm.
- Once the coats have been applied, it is important to cover the tank with damp jute sacking or plastic sheeting for at least one week for a good curing of the cement. This allows the cement to develop its high strength and avoids the risk of appearing cracks (T.B. 2.05).
- A metal cross piece should be connected to the pipes to anchor them in the mesh before plastering.
- The overflow pipe should be foreseen with a screen or a siphon to avoid access to vectors.
- To protect the stored water from getting contaminated, the tank should be foreseen with a cover:
 - To make a closed cover on the tank, it is possible to include reinforcing bars within the wall mesh forming a domed structure that is covered with mesh and plastered with cement plaster. An inspection hole with a lid should be foreseen in the tank cover.
 - Alternatives for the "ferrocement" cover are a reinforced concrete slab (attention for the weight) with inspection hole, a plastic lining or a solid metallic, plastic or fibreglass lid.
- Make sure there is a correct evacuation system for the overflow and the spilled water if collection is done directly at the tank. It should be avoided that laundry or dishes will be washed directly at the tap of the reservoir.
- Plastic sheeting installed inside a frame of vertical wooden stakes interwoven with horizontal wooden sticks can become a 1m³ reservoir for acute emergencies.



Key

1. Wooden stakes
2. Wire mesh
3. Overflow pipe with screen and/or siphon
4. Outlet pipe with tap / valve
5. Drainpipe with valve
6. Galvanised steel wire, 2 - 2.5 mm diameter
7. Exterior coat of cement mortar
8. Interior coat of cement mortar

Input

- Sharpened wooden stakes (50 mm x 50 mm x 1.750 mm)
- Sledgehammer
- Fine wire mesh (1.5 mm wire, 12 mm mesh)
- Rolls of fine wire (0.5 mm) and thick wire (2 - 2.5 mm)
- Cement, building sand and clean non-salty water
- Metal cross pieces to anchor galvanised pipes
- Galvanised iron pipes (0.3 m long, 3/4" for the outlet if fitted with a tap, otherwise 1" or better 1.5" for the drainpipe with a gate valve, 1" or 1.5" for the overflow, fitted with a screen)
- Mason's tools
- Jute sacking or plastic sheeting

T.B. 2.39 Distribution tapstand

Tap-stands are pre-assembled to be installed quickly and easily, allowing a rapid provision of water distribution points in emergency situations. Tapstands are sturdy to allow constant use. There are different models of tapstands available, but most of them do have 6 self-closing taps. With a maximum of 200 - 250 persons per tap, one tapstand can therefore be sufficient to provide water to 1200 - 1500 persons. Even with the self-closing taps, spillage is inevitable. Therefore is a proper drainage essential as of the beginning of the installation.

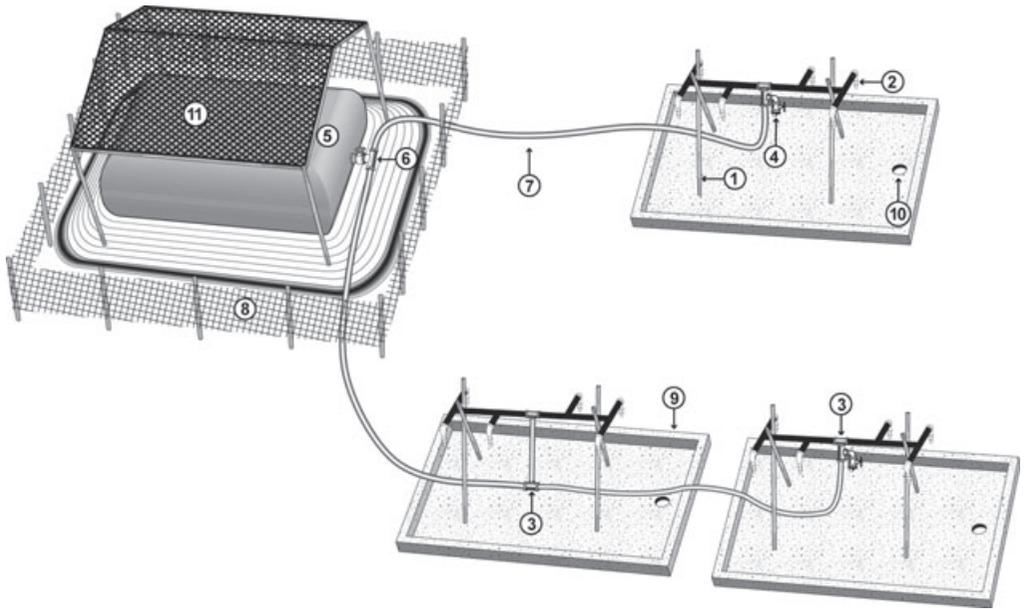
Installation

- Choose the site to install the tapstand(s). The site should permit a good drainage for rain and spilled water, and should be easily accessible for the users, specially for vulnerable groups.
 - Construct an apron with protective kerb at the chosen tapstand site, made with stones and covered with cement plaster (T.B. 2.05), or preferably lean concrete (similar to T.B. 4.02). This apron should drain the spilled water away and thus avoid mud and stagnant water near the water point. The spilled water should be disposed of via a soak away pit (T.B. 4.06), an infiltration trench (T.B. 4.07) or an evapo-transpiration area (T.B. 4.08). If the spilled water is not mixed with grey water (water coming from washing laundry or dishes on the apron), it doesn't need to pass via a grease trap, and it could also be used to irrigate a vegetable garden.
 - Assemble the tapstand in such a way that the distance in between the nozzle of the taps and the apron is slightly higher than the biggest water recipient in use by the beneficiaries (often a gap of 0.5 m is sufficient). This limited distance will reduce the amount of water falling next to the recipient, especially in windy places. For people (e.g. children) who often come to collect water with small (e.g. 5 litres) jerrycans, a small stand can be made under one or two taps.
 - Connect the tapstand to the reservoir. Ensure a correct pressure and flow at the taps by creating the right height difference between the tapstand and the reservoir and/or by choosing the right type and proper diameter of pipe (T.B. 2.36).
- A too high pressure can make it difficult (for children) to open the self-closing taps, and it can create a water hammering (bounce) effect.
- A too low pressure might result in a flow rate below the desired yield, and it can increase the leaking of certain self-closing taps.

An alternative is to provide an artificial pressure and flow by means of a hand pump or a motor pump (T.B. 2.36).

Remarks

- Make sure that water is freely accessible to all beneficiaries, specifically to vulnerable groups.
- A distribution tapstand kit might have two tapstands.
- In case the tapstand is connected to the reservoir with a non-collapsible pipe (e.g. Heliflex pipe), it is strongly recommended to bury it, even in an acute emergency.
- If several tapstands are to be installed at the same place, separate them enough to avoid beneficiaries pushing and shoving at busy times. The bigger reservoirs have two outlets, so it is possible to install a tapstand at each end to have two distinct distribution points. Also a tapstand supervisor can be appointed to avoid problems.
- To connect two tap-stands in series, undo the stopper from the Tee of the first tapstand and connect it with a piece of (Heliflex) pipe to the inlet of the second one. To have a good flow at all taps, do not place more than 2 tapstands in series.
- To ensure a minimum flow of around 10 l/min from each single self-closing tap, a nearby reservoir should be installed at least 1.2 - 1.5 m above the tapstand.
- The height of certain tapstands can be determined by the angle and the position of its legs.
- In case the water flow at the tapstand would be too high (risk of big splashes), it can artificially be reduced by installing a partially closed gate valve at its inlet.
- Check from time to time that the taps close properly. Solid particles in the water or objects inserted by users may prevent correct closure and therefore will increase water losses.
- When a soak away pit is chosen to dispose of the waste water, allow a minimum distance of 3 m away from the tapstand.
- During the first days of an acute emergency, the evacuation of the spilled water can be done via a gravel pit, while constructing a correct apron.



Key

1. Tapstand
2. Self closing taps
3. Double connection (different models)
4. Stopper and chain
5. Reservoir
6. Reservoir outlet and tee
7. Delivery pipe towards the tapstand
8. Fence
9. Apron with a protective kerb
10. Drain towards the infiltration system / garden
11. Roof

Input

- Reservoir for water supply
- Tapstand kit(s)
- Delivery pipes
- Material to make apron (T.B. 2.04)
- Material to make roof (leaves, shadow net, plastic sheeting, poles, timber, rope, tools)
- Spanner to fix the tapstands' legs
- Hook spanners



Safe Excreta Disposal

Narrative

Technical briefs

- T.B. 3.01 Defecation fields
- T.B. 3.02 Trench latrines
- T.B. 3.03 Improved trench latrines
- T.B. 3.04 Simple pit latrines
- T.B. 3.05 Latrine slab
- T.B. 3.06 Children's pit latrines
- T.B. 3.07 Ventilated Improved Pit (V.I.P.) latrines
- T.B. 3.08 V.I.P. latrine slab
- T.B. 3.09 Twin pit latrine
- T.B. 3.10 Pour-flush latrines
- T.B. 3.11 Septic tank
- T.B. 3.12 Raised pit latrines in problem soils
- T.B. 3.13 Emptying latrines and/or septic tanks

Chapter 3



3.1 Why have excreta to be disposed of correctly?

Human excreta transmit many infectious diseases. The pathogens leave the body of the infected person via the excreta and can then be transmitted to healthy individuals. This problem is particularly acute in health care facilities due to the high number of sick people present and to the high level of infectiousness of their excreta.

Five types of excreta-related diseases or transmission routes may be identified:

- Faeco-oral transmission (bacterial and non-bacterial)

Pathogens are transmitted by direct contact (hands) and domestic contamination (water, food and objects contaminated by excreta). Pathogens may be viruses, bacteria, protozoa and certain helminths. The list of faeco-orally transmitted diseases includes notably amoebic dysentery, cholera, giardiasis, hepatitis A and typhoid fever.

- Helminths (worms) transmitted by the soil

Helminth eggs have a latent period between the moment they are excreted and the moment they become potentially infectious. The transmission of these “geo-helminths” takes place through the contamination of soil and/or crops. It mainly concerns ankylostoma, ascaris and strongyloides. Infection by these helminths is very frequent and the prevalence may be higher than 90% in certain populations.

- Beef and pork tapeworms (taenia)

Cattle and pigs are intermediate hosts of taenia. The transmission cycle involves the contamination of soil and forage by human excreta, then the ingestion of undercooked meat by humans.

- Water-based helminths

The excreted eggs of those helminths pass part of their life cycle in one or several intermediate aquatic hosts (snails, crustacean, fish), before becoming infectious to humans. An example is schistosomiasis. Its transmission cycle involves the contamination of surface water by human excreta, development within a snail host and finally the penetration of the skin of a new human host when he enters the water.

- Excreta-related diseases transmitted by insect vectors

This includes all the diseases, which can be transmitted by “insects” like flies and mosquitoes, which breed in environments containing excreta (e.g. *Culex pipiens* mosquito that transmits filariasis).

3.2 What does the term safe excreta disposal mean?

The term “excreta” includes urine and faeces. Urine is less dangerous than faeces, except in the case of typhoid, paratyphoid, leptospirosis and one type of schistosomiasis (*Schistosoma Haematobium*). The main objective of safe excreta disposal is to reduce the transmission of diseases due to environmental contamination by faecal matter or the proliferation of vectors. This objective can mainly be reached through excreta containment.

The health impact of excreta disposal activities is difficult to evaluate however. It is generally agreed upon that a health impact will only be achieved if these activities are linked to improved water supplies, and individual and collective hygiene. It might also be necessary to combine excreta disposal with vector control methods (e.g. spraying).

For each of the five types of excreta-related diseases, following respective control measures can be proposed (see table hereunder):

Control measures	Faeco-oral transmission	Helminths transmitted by soil	Beef and pork tapeworms	Water-based helminths	Insect vectors
Safe excreta disposal (providing latrines / toilets)	X	X	X	X	X combined with vector control
Improvement of water quantity and quality (e.g. boiling of water)	X	-	-	-	-
Improvement of shelter conditions	X	-	-	-	-
Improvement of hygiene practices (e.g. hand washing, covering food)	X	-	-	-	X
Health promotion	X	X	X	X	X
Treatment of excreta before its use for fertilizing crops	X	X	X	-	-
Inspection and thorough cooking of meat	-	-	X	-	-
Inspection and thorough cooking of fish and aquatic plants	X	-	-	-	-
Control of intermediate hosts (e.g. snails in irrigation canals)	-	-	-	X	-
Reduction of contact with potentially contaminated water	-	-	-	X	-

3.3 Where / When should safe excreta disposal management be implemented and by Who?

A distinction should be made between:

- First phase (acute) emergencies.
- Chronic emergencies and stabilized situations.

In the first phase of an emergency, where there is a large concentration of people (e.g. refugee camps, collective centres), or where the normal sanitation structures are destroyed due to a (natural) disaster, it is essential to provide simple defecation facilities immediately. These facilities are provisional and need to be improved or replaced progressively over time by more suitable structures as the situation develops into a chronic emergency. In chronic emergencies as in stabilized situations, factors like local practices and socio-cultural issues should dictate the choice of the techniques used.

In the first phase of an emergency, the aid-agency will often have to implement and to maintain (cleaning and repairing) the facilities. In chronic emergencies and certainly in stabilized situations, community participation will be essential for correct excreta disposal management. In those cases, the users should be included as much as possible in the choice, the implementation and the maintenance of the excreta disposal facilities. The authorities can also have an impact on the choice of the excreta disposal method, because standardised facilities are desired, for example.

It should be verified if the users can provide their own anal cleansing material. If not, the aid-agencies might have to supply appropriate material that doesn't fill up the latrine pits too fast.

A gradual improvement of the excreta disposal facilities is also valid for health structures, even if those facilities will have to be conform to the essential requirements (T.B. 1.08) already from the start (e.g. upgrade from improved trench latrines to simple pit latrines). Appropriate material for anal cleansing should be readily available.

Correct sanitary facilities are extremely important for female teenagers and adults, certainly during their period. It might therefore be important to integrate washing basins and drying lines within female sanitary blocks, for the ladies to be able to wash their reusable sanitary towels. A waste bin in the neighbourhood of the sanitary facilities is essential for the disposal of (single use) sanitary towels.

3.4 How should safe excreta disposal be managed?

3.4.1 Planning and organisation

For correct planning and organisation of safe excreta disposal, it is necessary to follow all the different steps described in chapter 1. Some specific points of the assessment phase directly related to excreta disposal are gathered below.

As only simple and temporary excreta disposal solutions will be chosen for the first phase of the emergency, the information needed before implementation is limited and can be collected during the initial assessment. Some basic data on the physical nature of the site, the demography, the anal cleansing habits of the population and the material available are sufficient to determine the first phase strategy.

An in-depth assessment with the participation of the users will be needed to define a safe excreta disposal strategy for chronic emergencies and stabilized situations. For facilities to be fully functional, a lot of information needs to be collected and analysed. In general the choice of an excreta disposal technique depends on:

- Socio-political factors:
 - Authorities that forbid or enforce a method of excreta disposal.
- Demography of the population (number of beneficiaries).
- Socio-cultural and religious factors: particularly traditional and local attitudes and practices concerning excreta disposal:
 - Separation of the sexes.
 - The need for privacy.
 - Position (sitting or squatting).
 - Method of anal cleansing (wipers or washers), material used, its disposal.
 - Menstruation (material used, its disposal or being washed and reused).
 - Particular orientation of the latrines.
 - Taboo places and/or practices (e.g. defecating on top of each others excreta).
 - The acceptability of emptying a latrine pit.
- The physical nature of the site:
 - Available space: public, cluster or family type latrines; emptying or replacing when full.
 - Soil: type; available depth and ease to excavate; infiltration rate; stability; resistance against weight (heavy superstructure).
 - Water: availability in sufficient quantities (in case of anal cleansing with water and pour-flush latrines); different resources and their proximity (risk of pollution); level of the water table and its seasonal variations (risk of pollution); natural drainage of runoff water; risk of flooding.
- Climate:
 - Precipitation patterns (e.g. rainy season).
 - Temperature (important for vectors).
 - Main wind direction (odour).

- Available resources:
 - Financial (material and labour costs have an influence on the type and quantity of latrines).
 - Materials and tools (if locally available, there will be an impact on the construction time and costs, but also on the environment).
 - Human (skills and experience to construct the facilities).
- Time:
 - Constraints (short time frame to build facilities in emergency situations).
 - Lifespan (adapted to each situation but it has to be considered from the start).
- Operation and Maintenance (taken in charge by the users or the aid-agency).

The system should be chosen with all this information in mind, whilst remaining simple, cheap and above all easy to install and maintain (by the population / beneficiaries).

There are many excreta disposal techniques. In each situation the chosen technique should be adapted to the context, the site conditions and the users (their culture and habits). If these issues are ignored, the facilities will most probably become unused after a while and/or get damaged. The sanitary facilities may even create a health risk by themselves.

3.4.2 Technical process

In general, an excreta disposal technique may be considered acceptable when:

- It isn't harmful for public health:
 - It contains the excreta in one place.
 - It does not create an attraction for insects or any other animal.
 - It is not a source of pollution for the water points and the surrounding environment.
- It provides a certain comfort to the users:
 - It is adapted to the local habits.
 - It is accessible to the users (e.g. pathways).
 - It is not a nuisance in terms of odour or sight.
- It gives a minimum of privacy:
 - Gender has to be taken into consideration (separate excreta facilities for men and women might have to be constructed, certainly in public buildings like schools and health structures).
 - Special facilities for menstruating women and girls might have to be considered (e.g. discrete washing places for sanitary towels).
 - There should always be a separation in between the excreta facilities of the staff and the patients / visitors in health structures.
- It is safe:
 - Strong construction.
 - Not too dark inside.
 - Situated at such a place to prevent sexual violence (close enough to buildings / dwellings, lights available during the night time).
- It is adapted to specific population groups:
 - Handicapped and physically impaired people may need specifically adapted excreta disposal facilities in terms of distance, available space, equipment (e.g. handrails, seats). The design of these facilities will mostly be done on a case-by-case basis.
 - The distance that infected people (e.g. HIV / AIDS) can cover are limited, thus the excreta facilities should be close by.
 - Children should have latrines adapted to their size / physiognomy.

- It respects cultural requirements; besides the defecation position, the superstructure itself can have an influence if a facility is used or not:
 - Some cultures want it to be open, but most prefer to have privacy and thus a superstructure, with or without a roof (also depending on the type of latrine and rainfall).
 - Doors are not always available or affordable, so it should be checked if a spiral-shaped superstructure without a door is acceptable.
 - Local materials should be chosen as much as possible, as long as this doesn't have a too negative impact on the environment (e.g. deforestation).

For excreta disposal facilities to be more effective and to increase the public health benefits, they should be maintained regularly, and hand-washing equipment (including the soap or ashes, and water) should be available.

3.4.3 Early stages of the emergency (acute phase)

To have an impact with safe excreta disposal, it's important to rehabilitate the formerly used **“wild defecation areas”** once better facilities are at hand.

Defecation fields (T.B. 3.01) may provide a very short term emergency solution, particularly in hot dry climates and where there is enough space available.

Trench latrines (T.B. 3.02) may also be an adequate solution for acute emergency situations. The advantages over a defecation field are that the faeces are already better contained and possibly covered by the user with soil (located alongside the trench). The reduction of required space is another advantage.

Improved trench latrines (T.B. 3.03) are simple and rapid to build, certainly when prefabricated (plastic) slabs are available. Therefore, they can still be constructed during the first phase of an emergency. The slabs reduce the risk of people falling into the trench and the accessibility for flies is limited, at least if the lid is replaced on the slab. As the superstructure is divided in different compartments, improved trench latrines offer already about the same privacy as simple pit latrines. Combining some features of the trench latrines (simplicity and rapidity to construct) and the simple pit latrines (privacy, already improved safety), the improved trench latrines are an interesting intermediate solution. They are also the minimum option for health structures during acute emergencies.

If an auger or (hand) drilling equipment is available, a **borehole latrine** covered with a simple slab may be installed rapidly. Be aware however that the faeces often stick to the sides of the upper bore part, thus increasing the risk of attracting flies and augmenting the likelihood of blockages. Additionally, borehole latrines can only be made in areas with a very low water table (even during the rainy season).

In some parts of the world, defecation in **plastic bags** is a common practice (e.g. in slums where no latrines are available). In certain situations (e.g. lack of space in flooded areas, difficulties to dig in the debris after an earthquake), and if it is socio-culturally acceptable, this practice might be the only feasible solution during the first phase of an emergency. The bags should be biodegradable and preferably specially designed for the purpose (e.g. adapted shape and capacity, containing a specific product accelerating the biodegradation and/or absorbing the liquids). Obviously, the bags have to be collected, transported and disposed of (burial) in a safe manner. As the bags should be closed after use with a knot, the health risks are less compared to the collection of **night soil in buckets**, which is another common but unsafe practice in some places.

Whatever the emergency solution chosen, it is important to take steps to ensure that the facilities work well, are maintained properly and are utilised by the beneficiaries. Promotion campaigns and support from the local leaders are therefore essential. Hand washing equipment nearby the excreta disposal facilities should not be forgotten, even in acute emergencies.

3.4.4 Chronic emergencies and stabilized situations

Where simple means are used in the first stages of an emergency, different disposal techniques may be used in the later phases of an emergency and in stabilized situations. There is no formula to suit all circumstances. But based on the collected information as described above, it should be possible to choose the most appropriate solution that remains simple, cheap and above all, easy to install, to use and to maintain (possibly by the population / beneficiaries).

Simple pit latrines (T.B. 3.04) are the most common excreta disposal facilities to be found in population settings, because they are rather quick and easy to build. As these facilities are built to last for a longer time span, more attention should go to the pit and its lining, the slab (T.B. 3.05) and the superstructure. Often, small children cannot use a normal simple pit latrine due to the size of the defecation hole and the position of the foot rests. They are often also afraid to be enclosed inside the superstructure. Therefore it is important to implement **children's pit latrines** (T.B. 3.06) as well, specially in health structures where lots of children are present (e.g. feeding centres, paediatrics ward).

Ventilated Improved Pit (VIP) latrines (T.B. 3.07; 3.08) are mainly interesting for long-term settings, such as public buildings like schools and health structures. Their ventilation pipe with flytrap is a big advantage as it reduces considerably odour and fly nuisances. However, VIP latrines are rarely the ideal option in population settlements within chronic emergencies because they are rather difficult and expensive to build, certainly by families themselves without any support. Children might also be afraid to use a VIP latrine because of the semi-dark environment that has to be kept in its superstructure for proper functioning.

Twin pit latrines (T.B. 3.09) consist of two completely separated (VIP) latrines, of which only one is operational at the time. Once the first (VIP) latrine pit is full, the second one can be opened for use. When well designed, the full pit can be emptied manually, but only if a period of minimum two years has passed since it was last used. This minimum period is for the excreta to become completely harmless. This has the advantage that twin pit latrines can be used over and over again without any health risks. This can be extremely interesting for health structures in stabilized situations. However, in many cultures there are taboos related to the handling of excrement residues. It also requires a certain knowledge or training to use them correctly. The initial investment is considerable and therefore are twin pit latrines rarely used at family level. This kind of latrines can be used as / transformed into ecological sanitation facilities.

Dehydration sanitation (separation of urine and faeces) and **aerobic composting latrines** (adding domestic organic waste and aerating) are **ecological sanitation (Eco-San)** systems which should shorten the period before human waste can be handled safely. However, they are only to be implemented in areas where they are already known and practiced, or when a complete long-term latrines project is started with a serious integrated promotion campaign. They are mostly not appropriated for emergency situations.

Raised pit latrines (T.B. 3.12) above the ground level are one of the options to provide adequate sanitary facilities in difficult circumstances (e.g. high water table, flooding, rocky underground). However, a raised pit is often more difficult to build and the costs are often higher. Simple pit latrines, VIP latrines and twin pit latrines can all be raised.

Pour-flush latrines (T.B. 3.10) can be very interesting for populations that use water for anal cleansing, certainly as the siphon forms a seal that reduces the odour and fly nuisances. If the design is well made, it requires very little water to flush the latrine. However, enough water should be available in the direct neighbourhood to consider this option, certainly in settings with a lot of people. It is recommended as well to use the system only if the population is familiar with this technology, or when there are time and resources enough to promote their correct use and maintenance. Pour-flush latrines should be completely avoided when people are using solid materials (maize cobs, stones, leaves) to do their anal cleansing, as they will block the siphon rapidly.

Septic tanks (T.B. 3.11) connected to pour-flush latrines or flush toilets will separate the solids (faeces) from the liquids (mainly water). The faeces will decompose anaerobically within the septic tank, whereas the liquids need to be evacuated. As these liquids still contain a lot of pathogens, a decent infiltration or a closed sewer system will be needed to avoid health risks. Some septic tanks are foreseen with a percolator which treats the liquids to a certain extent, reducing the amount of pathogens before disposal.

Secondary wastewater treatment and complete sewage systems fall out of the scope of these guidelines.

Maintenance is a key element in the use of excreta disposal facilities. A dirty latrine will certainly not be used. Hand washing facilities with soap (or ash) nearby the latrines are essential to reduce the hazard of faecal-orally transmitted diseases.

3.4.5 Public versus family facilities

In the first phase of an emergency, **public facilities** are most often the only viable option for “safe” excreta disposal, because they have to correspond rapidly to a minimum level of quantity and quality. Also in chronic emergencies, this minimum level may only be obtained when public facilities are built by aid-agencies. Linked to the specific physical nature of the site (e.g. limited availability of space, high water table, rocky ground), it might be (technically) impossible for the people to construct their own latrine. Non-precarious situations may also require public facilities, like:

- Health structures: dispensaries, hospitals, feeding centres.
- Public places: markets, schools.

However, when a public facility is adopted for a population or for a central service (e.g. a hospital), it is indispensable to appoint a team that is responsible to ensure correct maintenance. This team will probably have to be remunerated for this service. The main advantage of **family latrines** over public facilities is the fact that they normally pose fewer maintenance problems. People normally take more care of their own latrine and have fewer problems with cleaning the dirt of their family members than of total strangers.

As family latrines are mostly closer to the dwellings, the chance of actually being used improves, certainly when the people themselves have built them. The smaller distance increases also the safety, certainly for women and girls as they may be victim of sexual violence when they go to the latrine (at night). It might be easier to persuade people to dig their own individual family latrine if a good promotion campaign is done and when construction material is (made) available.

If family latrines are not possible because of the population density or due to a lack of resources, an alternative is to construct one latrine per lot of three or four dwellings (or about 20 people), called a **cluster latrine**. The advantages are that the distances stay small and that the latrine is used by people who know each other and therefore can make arrangements for the maintenance. Another alternative to a high population density is to build centralized units at the edge of a living quarter or camp section where each family or group of families has access to its own latrine (preferably closed with a padlock), but this increases the distance in between the facilities and the dwellings.

The area allowed for latrines should also be big enough to dig new pits when the first ones are full. Another possibility is to empty the full latrines. Special equipment is required however (T.B. 3.13) and the dumping site for the excreta has to be well chosen to avoid health and environmental risks and nuisances.

3.4.6 Calculation of the effective and total volumes of a latrine pit

The pit latrine is the most common system of excreta collection in the world. To calculate the effective volume of a pit, proceed as follows:

$$V_{\text{eff}} = (N \times S \times Y)$$

- with:
- V_{eff} = effective pit volume in m³,
 - N = number of users
 - S = solids accumulation rate in m³/person year
 - Y = lifetime of the latrine in years

Use a solids accumulation rate of:

- 0.04 m³ per person a year for human waste retained in water; e.g. wet latrines (not recommended).
- 0.06 m³ per person a year for dry conditions; e.g. dry latrines.

Be aware that these figures are only indicators and can vary significantly:

- The effective pit volume may be increased by 30 to 50% if bulky anal cleansing materials are used (e.g. stones, maize cobs).
- For pits that are intensively used and only have a lifetime of maximum a year, the solids accumulation rates should be doubled.
- Soils with low permeability, will have a low infiltration rate, thus filling up a lot faster than initially expected, certainly when water is used for anal cleansing.

The effective volume represents the space available for excreta storage, but when calculating the total required pit volume, a free space with a depth of 0.5 m has to be added to the effective volume. This free space at the top of a full latrine is to avoid:

- unpleasant sights during use
- excreta splashing out of the pit during use,
- odour and fly problems after backfilling.

Thus the total volume is represented by:

$$V = (N \times S \times Y) + 0,5A$$

with: V = total required volume
A = pit base area

The bottom of the pit should be at least 1.5 m above the highest possible water table, because this reduces the chance of microbiological contamination of the groundwater virtually to nil in homogeneous soils. The required vertical distance for heterogeneous soils is difficult to predict however.

The suggested minimum lifetime of a simple family pit latrine that can't be emptied is 5 years. Public latrines for 20 users should last for about 2 years at least before they are full. Normal twin pit latrines should have a capacity of at least 2 years per compartment in order to render the excreta completely harmless before being emptied. Ecological sanitation systems can usually do with less time to render the excreta completely harmless, if there are well operated and maintained.

Rectangular pits can cave in rather easily, whereas circular holes have a more natural resistance against collapse because of the arching effect. Deep pits in soft sands and gravels, unconsolidated soils, (back)filled land, compressed mudstones and shale should always be lined. Soils with a significant amount of clay or high iron oxides content (e.g. laterite), or consolidated sedimentary rocks are less at risk of collapse. Nevertheless, a lining is always recommendable (in chronic emergencies and stabilized situations) for security reasons and to prolong the lifespan of a latrine.

Rocky bottoms in which it is difficult to excavate, flood prone areas or situations with a high water table may require raised latrines (T.B. 3.12). Still, infiltration of the liquids will have to be foreseen in the underground part of these structures. Sometimes the water table is that high that contamination of the groundwater can't be avoided. As such, it isn't a problem to contaminate the groundwater microbiologically, as long as it isn't used for domestic or health purposes, and/or for drinking water. It is also easier during emergencies to supply potable water than to evacuate excreta on a daily basis (except maybe if the faeces are stored in sealed plastic bags).

It's also important to drain runoff water away from the latrines to avoid erosion of the pit and the surroundings.

3.5 Further reading

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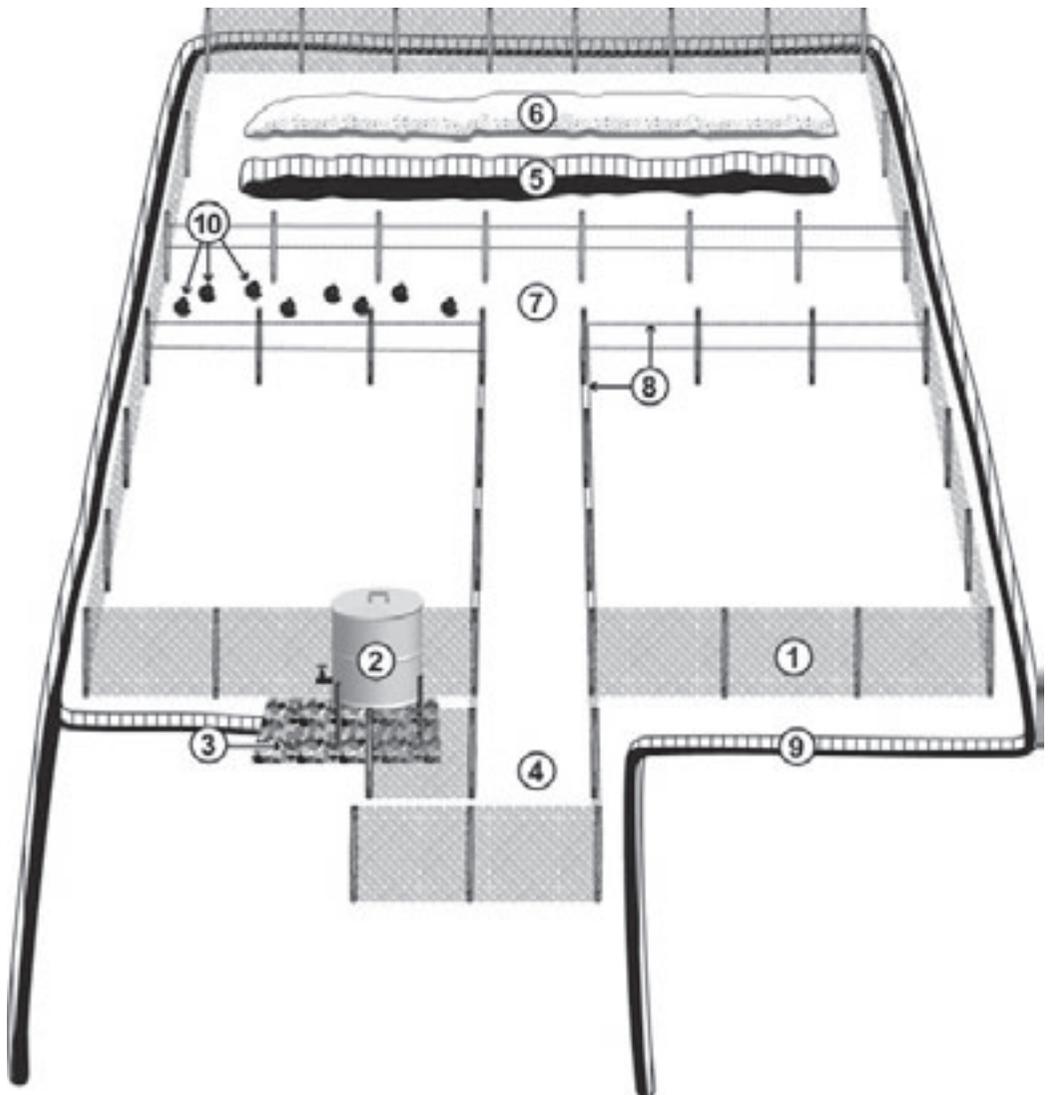
T.B. 3.01 Defecation fields

Defecation fields represent a basic disposal method to avoid excreta to be spread all over the camp. They are only justified in the very early stages of emergency situations, particularly in hot dry climates, where there is sufficient space for their implementation and when they are acceptable for the beneficiaries. Safer and more permanent solutions should be implemented rapidly.

Installation

- Choose a site away from fields where crops for human consumption are grown. It should be located downwind and away from living areas (at least 30 m), avoiding watercourses and at a reasonable distance (minimum 50 m) and preferably downstream from all water sources, storage and treatment areas.
- Prepare the site: remove all debris, determine the depth of the water table and bring in the needed material and equipment.
- Fence the area (for example with plastic sheeting), and put up a zigzag entrance in order to limit the risk of animals straying and to keep as much privacy as possible (at least a strict gender separation). Additional movable screens can be placed inside the area to improve the privacy and to indicate where to defecate.
- Dig drainage channels around the defecation field fence to prevent potential runoff water from entering.
- Put a water container with a tap and soap (or ash if soap isn't available) in an obvious place (near the exit) to allow hand washing after defecation. Make sure that an infiltration system, at least a gravel pit or preferably a soak away pit (T.B. 4.06) is foreseen.
- Provide anal cleansing material if needed, and a waste bin for sanitary towels in the women's section.
- Allocate two trained guards (mind the gender) who should manage the correct use of the defecation field.

Key	Input
1. Fence (e.g. plastic sheeting)	- Stakes and ropes (fence and defecation zone)
2. Closed water container with tap / soap or ash	- Sledgehammer
3. Infiltration system for wastewater (e.g. gravel pit)	- Non-transparent plastic sheeting (or local material)
4. Zigzag entrance	- Hammer and nails
5. Trench (optional)	- Shovels, hoes, picks to dig runoff drainage / gravel pit / trench
6. Soil for burying excreta (optional)	- Stones / gravel
7. Defecation zone in use	- Water container (e.g. at least a 200 l drum or better a 2000 l bladder) with tap
8. Ropes and stakes indicating the defecation zone in use	- Soap or ash
9. Runoff drainage	- Anal cleansing material (if required)
10. Excreta	- Waste bin for sanitary towels (if required)



Remarks

- Defecation fields are not really suited during the rainy season as runoff water risks to spread the excreta, and thus the contamination over a big area. Defecation fields should also be protected against floods.
- The objective should be to replace the defecation fields as quickly as possible with a more hygienic system; e.g. improved trench latrines (T.B. 3.03), simple pit latrines (T.B. 3.04).
- Defecation fields should be clearly marked and provided with enough space; about 0.5 m²/person day (pathways not included).
- It is compulsory to build gender separated defecation fields. Simply dividing the male and female sections with plastic sheeting and providing two separate entrances may not be acceptable by the users.
- Lighting at the defecation field is highly recommended for safety / security reasons.
- It is strongly recommended that the defecation field is utilized according to a pattern in order to use the available space most effectively. Some poles and ropes, which position has to be changed after a while, will indicate the defecation zone in use (each row maximum 20 m long, about 1.5 m wide). To encourage the full usage of a defecation zone, the guards can relocate a screen that provides some additional privacy along the row as it fills up with excreta; from the outer side of the zone towards the central alley. By using the row's entrance also as an exit avoids that people have to pass an area that is already covered with excreta.
- When a bulldozer is available, it can be used to scrape off the ground surface at the end of the day, to be able to reuse the defecation field again. The excreta can be pushed into a trench at the edge of the field and covered with the excavated soil, to reduce the attraction of flies. In homogeneous soils, the bottom of the potential trench should be at least 1.5 m above the highest groundwater table. The required vertical distance for heterogeneous soils is difficult to predict. The water table depth can be estimated by verifying the water level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe in the ground, as deep as 1.5 m beneath the required trench depth. When pulled out, the rod or (the earth inside) the pipe should be dry. If not, the trench depth should be adapted accordingly. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level.
- It is recommended to add wood ash every day to the excreta (within the potential trench). This gives a perceptible odour reduction. Active lime will also reduce the odours, but might slow down the decomposition of the excreta.
- If a simple infiltration system with stones and gravel is placed under the water container for hand washing, follow closely if it doesn't clog up too fast with soil and greasy soap residues. If so, an emergency grease trap (T.B. 4.04) will have to be added.
- People could also defecate on a small pile of sand, after which they have to scoop up their excrements with a shovel and dispose of them in a drum or trench. This technique requires less space but more supervision.

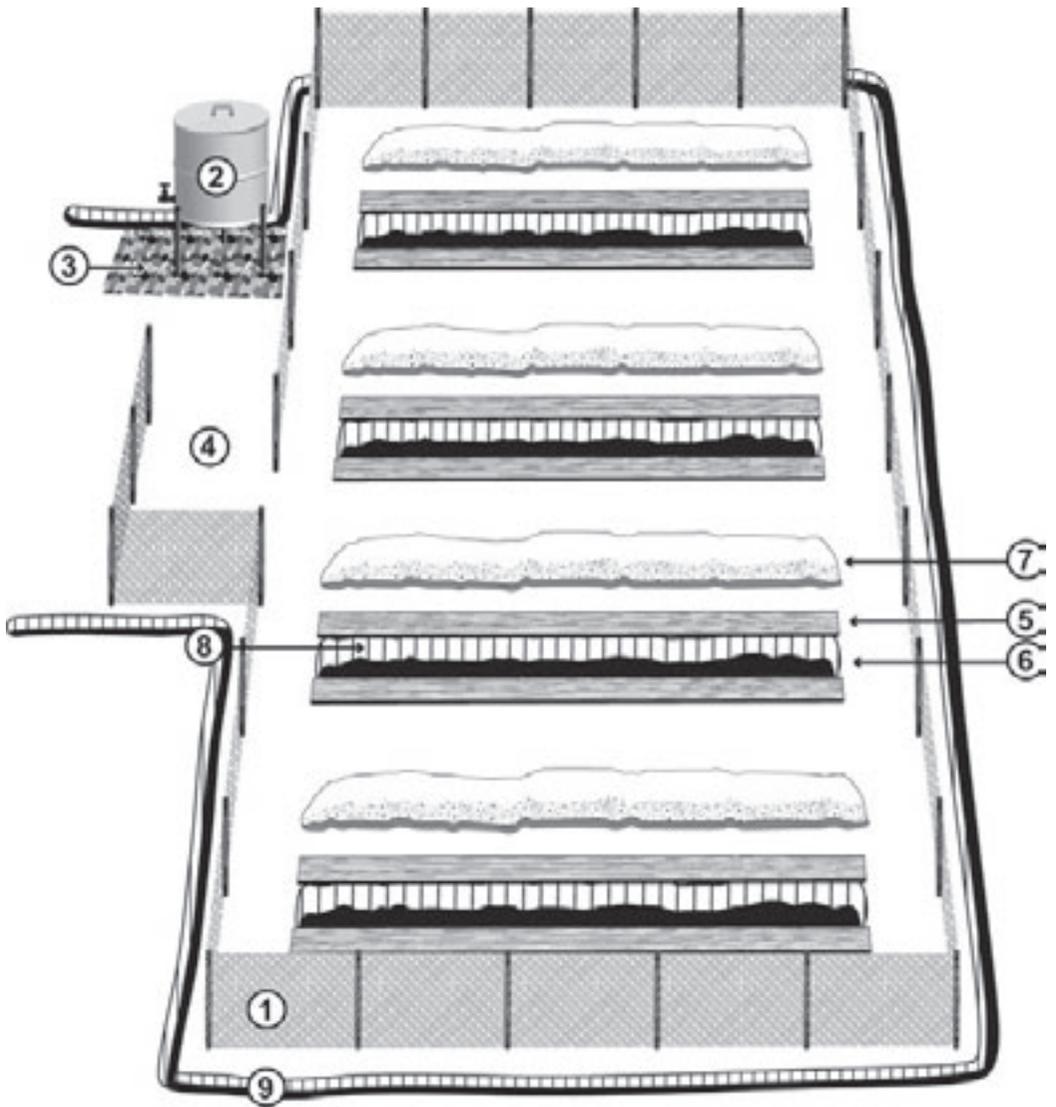
T.B. 3.02 Trench latrines

Trench latrines represent a method of excreta disposal, which is simple and rapid to implement. They are only justified in acute emergency situations, until more permanent solutions are constructed. The assessment for more permanent solutions should start as soon as the trench latrines are implemented.

Installation

- Choose a site with stable soil, downwind from living areas. It should be at least 30 m away (more for fissured underground and limestone) and downhill from all water sources, storage and treatment facilities.
- Prepare the site: remove all debris, implement a soil texture test (T.B. 4.05), determine the depth of the water table and bring in all the needed material and equipment.
- Fence the area (for example with plastic sheeting), and put up a zigzag entrance in order to limit the risk of animals straying and to keep as much privacy as possible (at least strict gender separation).
- Use string lines to lay out the trenches, 0.3 m wide (less for children) and at least 1.5 m apart from each other. Allow about 3.5 m length per 100 users.
- Dig trenches of about 0.9 m deep (1.5 m deep if a mechanical excavator is available). In unstable soils, it might be necessary to dig trenches less than 0.9 m deep (but they will fill up faster). Place the excavated soil near the side of each trench for the users to cover their excreta after each use, as to reduce the odours and the attraction of flies. Make sure there is enough space in between the trench and the excavated soil.
- Lay planks along the two sides of the trench to ensure a good foothold and to limit erosion of its edges. For safety reasons, interconnect the opposite planks with beams and anchor them to avoid that they slide away.
- Dig drainage channels around the trench latrines' fence to prevent runoff water from entering.
- Put a water container with a tap and soap (or ash if soap isn't available) in an obvious place (near the exit) to allow people to wash their hands after defecation. Make sure that an infiltration system, at least a gravel pit or preferably a soak away pit is foreseen.
- Provide anal cleansing material if needed, and a waste bin for sanitary towels in the women's section.
- Allocate two trained guards (mind the gender) who should manage the correct use of the trench latrines.

Key	Input
1. Fence (e.g. plastic sheeting)	- Stakes, rope and sledgehammer (for the fence)
2. Closed water container with tap / soap or ash	- Non-transparent plastic sheeting (or local material)
3. Infiltration system for wastewater (e.g. gravel pit)	- Hammer and nails
4. Zigzag entrance	- Tape measure, string lines, sticks
5. Planks	- Picks, hoes, shovels (also to cover the excreta)
6. Trenches (0.3 m wide)	- Planks (or wooden poles)
7. Soil for burying excreta	- Stones / gravel
8. Band of plastic sheeting (optional), partly lying underneath the planks, partly hanging in the trench (useful for trench maintenance and against erosion)	- Empty cans (to handle soil for burying excreta)
9. Runoff drainage	- Water container (e.g. at least a 200 l drum or better a 2000 l bladder) with tap
	- Soap or ash
	- Anal cleansing material (if required)
	- Waste bin for sanitary towels (if required)



Remarks

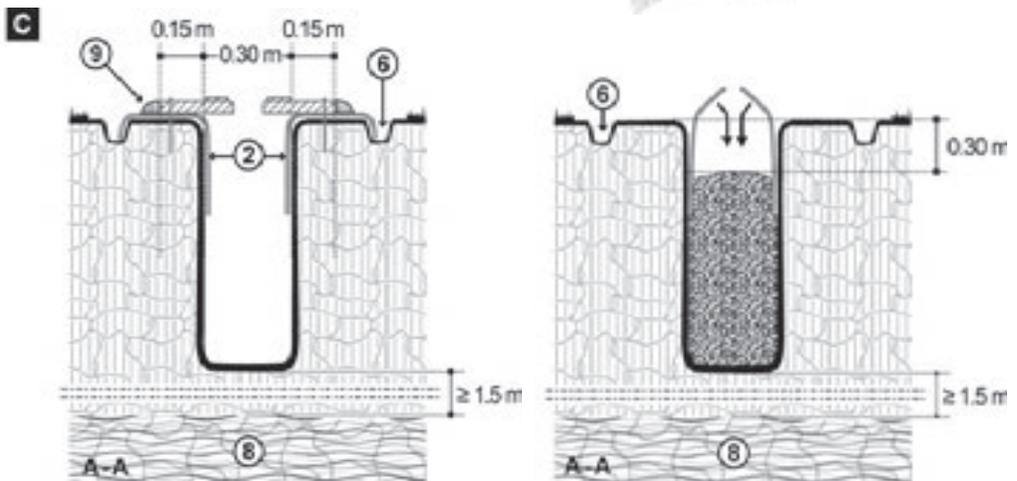
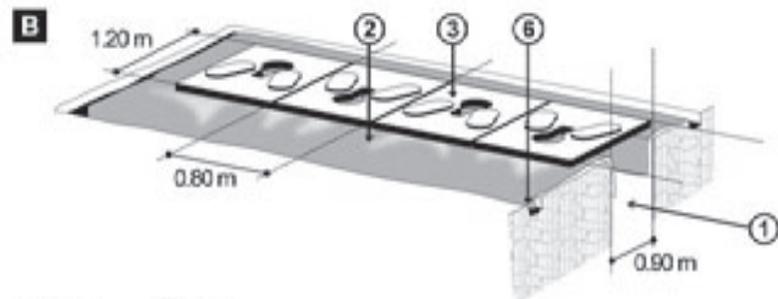
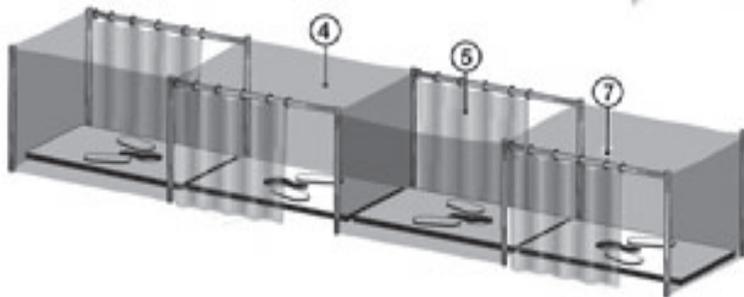
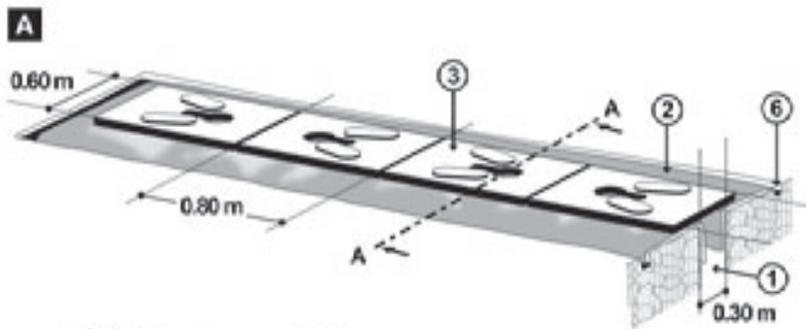
- Trench latrines should be clearly marked and protected against flooding.
- In homogeneous soils, the bottom of the trenches should be at least 1.5 m above the highest possible groundwater table. The required vertical distance for heterogeneous soils is difficult to predict however. The depth of the water table can be estimated by verifying the water level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½” galvanized pipe in the ground, as deep as 1.5 m beneath the required trench depth. When pulled out, the rod or (the earth inside) the pipe should be dry. If not, the trench depth should be adapted accordingly. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level.
- The planks may be replaced by wooden poles. To keep them from rolling away, dig the poles slightly in.
- It is compulsory to build gender separated trench latrines areas. Simply separating the male and female sections with plastic sheeting and providing two separate entrances may not be acceptable to the users.
- Special latrines with facilities such as a seat and handrails should be built for physically impaired people, as trench latrines can't be used by some of them (incapable to squat). Potties are an alternative for children.
- Lighting the trench latrines at night is highly recommended for safety / security reasons.
- To encourage full usage of the trenches, ropes or screens providing some privacy can indicate those in use.
- Try to make sure that the users cover their excreta with a layer of soil, located next to the trench.
- If possible, add wood ash to the trenches at least once a day. This gives a perceptible odour reduction. Active lime will also reduce the odours but might slow down the decomposition of the excreta.
- If a simple infiltration system with stones and gravel is placed under the water container for hand washing, follow closely if it doesn't clog up too fast with soil and greasy soap residues. If so, an emergency grease trap (T.B. 4.04) will have to be installed.
- Once the trenches are nearly full (about 0.3 m from the surface), dismantle and backfill them. Don't dig at this place again for at least two years, but plant water-absorbing trees (e.g. mangos) to re-stabilize the soil.
- The objective should be to replace the trench latrines as quickly as possible with a safer and more hygienic system; e.g. improved trench latrines (T.B. 3.03), simple pit latrines (T.B. 3.04).
- If people want to build their own facilities immediately, a shallow family trench can be an option. Apart from the size (e.g. 0.5 m x 0.3 m x 0.5 m deep), the principle is the same as for normal trench latrines.

T.B. 3.03 Improved trench latrines

Improved trench latrines represent a method of excreta disposal, which combines the features of normal trench latrines (simple and rapid to implement) and simple pit latrines (privacy and an already improved safety). Although they are only justified in emergencies, they do offer an interesting solution in between the normal trench latrines and the (family) simple pit latrines. They are also the minimum option for health structures during acute emergencies.

Construction

- Choose a site with stable soil, at least 30 m away (more for fissured underground and limestone) and downhill from all water sources, storage and treatment facilities. The facilities must have an easy access, not less than 5 m and not more than 50 m away from the dwellings (< 30 m from health structure shelters).
- Prepare the site for construction: remove all debris, put up a temporary fence, implement a soil texture test (T.B. 4.05), determine the depth of the water table and bring in all the needed material and equipment.
- Lay out the trenches, using string lines. Allow per trench about 3 m length (4 slabs), for 80 - 100 users. Their width depends on the prefabricated slabs size:
 - For small (plastic) slabs of 0.8 m x 0.6 m, foresee a trench of 0.3 m wide,
 - For big (plastic) slabs of 1.2 m x 0.8 m, foresee a trench of 0.9 m wide.
- Dig the trenches at least 0.9 m and maximum 1.5 m deep.
- Dig a drainage channel around the improved trench latrines to lead runoff water away from the trench.
- Put plastic sheeting of at least 1 m wide on the ground along the sides of the trench. Half of its width should be laying flat on the ground (preferably up to the drainage channel to reduce the risk of erosion), where the other half should be folded so it hangs inside the trench. This plastic sheeting will ease the daily maintenance and the backfill of the improved trench latrines once full.
- Put the prefabricated (plastic) slabs down in such a way that the defecation holes are alternated in direction; 180° shifted, meaning back-to-back for small slabs and side-to-side for big slabs (as per figures) and secure them (e.g. with metal pegs).
- Put clay (or compacted earth) around the slabs to avoid direct infiltration of runoff water, rendering the trench edges unstable.
- Install vertical stakes at the corners of the slabs. By adding some horizontal sticks on top and diagonal poles at the sides, a more solid structure will be obtained. To have enough space available inside the superstructure, the vertical stakes should be about 0.15 m away from the corners of the small slabs.
- Wrap a long piece of plastic sheeting of about 2 m wide (high) around an outer corner stake, and secure it (e.g. with nails). The remaining part of the plastic sheeting has to be rolled off around the other vertical stakes in a zigzag movement (as per figure), in order that the entrances are alternated. This principle allows the rapid construction of a superstructure.
- Attach bands of plastic sheeting to the horizontal sticks of the structure to form the latrines' curtains. Provide each curtain with horizontal sticks (bottom and middle), so that it won't open constantly by the wind. A roof of plastic sheeting should preferably be foreseen as well, certainly in areas where it rains a lot.
- Put a water container with a tap nearby the improved trench latrines to allow hand washing after defecation. Make sure that an infiltration system (T.B. 4.06; 4.07; 4.08), preferably with a grease trap (T.B. 4.04), is foreseen.



Operation and Maintenance

- Provide water and soap (or ash), and anal cleansing material if required (certainly in health structures).
- Try to ensure that the cover is always replaced over the defecation hole to reduce breeding of flies and to lessen bad odours in and around the improved trench latrines' superstructure.
- Try to have the slabs and surroundings cleaned / disinfected on a daily basis. Never put disinfectants (e.g. chlorine products) or any other chemicals in the trench as they might inhibit the natural decomposition of the faecal material. The only situation in which it is permitted to pour disinfectants or human wastes mixed with a (strong) chlorine solution into an improved trench latrine is during an epidemic of highly infectious diseases (e.g. cholera, Viral Haemorrhagic Fevers).
- Try to add wood ash into the trenches on a daily basis. This gives a perceptible odour reduction and might accelerate the elimination of pathogens. Active lime will also reduce the odours but might slow down the decomposition process of the excreta.
- Follow closely if the wastewater facilities function properly and do the necessary maintenance on the grease trap (T.B. 4.04).

Key	Input
A. Positioning small slabs (0.8 m x 0.6 m)	- Temporary fencing material
B. Positioning big slabs (1.2 m x 0.8 m)	- Tape measure, string line, sticks
C. Cross section of trench (during and after use)	- Shovels, hoes, picks, miner's bar
	- Clay / compacted earth (potentially some concrete)
1. Trench	- Prefabricated slabs with lid and pegs
2. Band of plastic sheeting	- Stakes and ropes (for the superstructure)
3. Prefabricated slabs with lid (latter not indicated)	- Non-transparent plastic sheeting
4. Plastic sheeting zigzagging around the poles	- Nails and hammer
5. Curtains of plastic sheeting	- Water supply with tap and evacuation system (e.g. at least 200 l drum per 4 cubicles or better)
6. Runoff drainage	- Soap or ash
7. Attachment of the curtain	- Anal cleansing material, (if required)
8. Aquifer (water table)	- Waste bin for sanitary towels (if required)
9. Impermeable layer (e.g. clay)	

Remarks

- When choosing the site, ensure that buildings (e.g. health structures) and living areas are not downwind of the improved trench latrines.
- Before the trenches can be excavated, the groundwater level has to be determined. In homogeneous soils, the bottom of the trench should be at least 1.5 m above the highest possible groundwater table. The required vertical distance for heterogeneous soils is difficult to predict however. The depth of the water table can be estimated by verifying the water level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe in the ground, as deep as 1.5 m beneath the required trench depth. When pulled out, the rod or (the earth inside) the pipe should be dry. If not, the trench depth should be adapted accordingly. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level.
- In less stable soils, the trench will have to be lined with vertical boards (wood, corrugated iron) that are kept in place with horizontal struts. Sandbags filled with stabilised soil can also be an alternative.
- If a high water table, rocky or sandy soil prevents the excavation and use of trenches, elevated platforms may be built. It is also possible to use 200 litre drums, (partially) buried in the ground with a defecation opening at the top, or to use slabs that can be set on top of the opened drums.
- It might be necessary to build separate improved trench latrines for men and women, and foresee certainly separated facilities for the staff in health structures.
- A waste bin close to the improved trench latrines is recommended for the disposal of sanitary towels.
- In case the sanitary towels of menstruating women and girls are washed and reused, it might be appreciated if a discrete washing area with drying lines is foreseen nearby the improved trench latrines for the ladies.
- Slabs with adapted dimensions for the defecation hole and the footrests might have to be installed for small children, certainly in health structures (e.g. paediatrics ward, feeding centre, Out Patient Department). Potties, which can be emptied in the improved trench latrines, can be an alternative.
- If there are physically impaired persons amongst the population, make sure to equip some of improved trench latrines with specific features, such as a (removable) seat and handrails, because some of them will be incapable to squat (section 3.5 Further reading). Clean and disinfect these features regularly.
- Lighting at the improved trench latrines at night is highly recommended for safety / security reasons.
- Insecticide Residual Spraying (T.B. 7.15) of the plastic sheeting superstructures has potentially a high impact on the fly population.
- When the trenches are nearly full (about 0.3 m underneath the slabs), they should be dismantled and backfilled. Remove the superstructure and the slabs, and disinfect them. When the plastic sheeting of the superstructure is still in good condition, it can stay connected to the stakes, and be "replanted" around a new trench where the prefabricated slabs are already installed. Water-absorbing trees (e.g. mangos) can be planted inside the old trench to re-stabilize the underground. Before the backfilling takes place, the part of the band of plastic sheeting that is positioned on the ground can be folded towards the inside of the trench, on top of the excreta. Do not dig at the same place again for at least two years.
- If people want to build their own facilities immediately, a shallow family improved trench can be an option. Apart from the trench size (e.g. 0.5 m x 0.3 m x 0.5 m deep or 0.9 m x 0.5 m x 1.0 m deep, depending on the slab size) and the reduction in number to one slab, the principle is the same as for normal improved trench latrines.

T.B. 3.04 Simple pit latrines

For prolonged periods, the simple pit latrine is one of the easiest and fastest means of disposing of human wastes. If well designed and built, correctly sited and well maintained, it contributes significantly to the prevention of faeco-oral diseases. From a public health point of view, family latrines are normally preferred over public latrines because they are often better maintained by the owners.

Construction

- Choose a site at least 30 m away (more for fissured underground and limestone) and downhill from all water sources, storage and treatment facilities. The latrine (battery) must have easy access, not less than 5 m and not more than 50 m away from the dwellings (< 30 m from the buildings within a health structure).
- Prepare the site for construction: remove all debris, flatten the surface, put up a temporary fence, implement soil texture and permeability tests (T.B. 4.05), determine the depth of the water table and bring in the needed material and equipment.
- Lay out the base area (foundation) of the latrine battery as per figure B, using string lines.
- Excavate the base platform and trench, as per figure B. Keep the sides of the trench as straight as possible to obtain relatively smooth concrete surfaces afterwards.
- Prepare and install the required reinforcing bars inside the base excavation as per figure C. Make sure that the reinforcing bars stay at least 30 mm away from the sides (use spacers for the lower re-bars). Vertical reinforcement bars can be used every 2 m to keep the middle and upper re-bars in place during the casting of the concrete.
- Prepare and pour the concrete (300 kg/m³; T.B. 2.05) inside the base excavation, and vibrate the concrete to remove all the air (e.g. poke it rigorously with a reinforcing bar). Keep the concrete moist for a week with plastic sheeting or jute sacking that needs to be wetted twice a day.
- Start digging the latrine pit within the base, when its concrete has hardened for at least 3 days. Do not dig underneath the concrete base. In homogeneous loam or clay soils (T.B. 4.05), the maximum pit depth is limited to 2.5 m, and its bottom should be at least 1.5 m above the highest possible water table.
- Install perforated corrugated iron sheets vertically in the pit, overlapping each other partly, imbedded by 0.2 m in the soil, and fixed to the concrete base (as per figure A). The perforations can be done by drilling small holes or by means of a hammer and a pointed chisel.
- Install prefabricated slabs with their cover on the concrete base, once the pit is completed. To ensure a secure seating, the slabs should be fixed to its base (overlaps of at least 0.1 m) with a 10 mm thick mortar layer (T.B. 2.05). An extra anchoring with metal pegs is advised for plastic slabs.
- Construct a superstructure around the slab, adapted to local preferences. It may be built with masonry-work, wood, corrugated iron or non-transparent plastic sheeting, but preferably local materials (e.g. branches and mud) as long as this doesn't have a too negative impact on the environment (e.g. deforestation). The superstructure should have a door if local habits dictate. A spiral-shaped superstructure without a door can also be used for a single or double latrine.
- Fit a roof to the superstructure with its slope carrying rainwater towards the back of the latrines.
- Make a drainage channel at the back and the sides of the latrines to lead the runoff water away, thus protecting the pit walls against erosion.
- Provide hand washing facilities nearby the latrines. Make sure that a grease trap (T.B. 4.04) and an infiltration system (T.B. 4.06; 4.07; 4.08) are foreseen.

Operation and Maintenance

- Provide water and soap (or ash), and anal cleansing material if required (certainly in health structures).
- Try to ensure that the cover is always replaced on the defecation hole to reduce the breeding of flies and to lessen bad odours in and around the latrine's superstructure.
- Try to have the slabs and surroundings cleaned / disinfected on a daily basis. Never put disinfectants (e.g. chlorine products) or any other chemicals in the pit as they might inhibit the natural decomposition of the faecal material. It is only permitted during an epidemic of highly infectious diseases (e.g. cholera, Viral Haemorrhagic Fevers) to pour disinfectants or human wastes mixed with a (strong) chlorine solution into a latrine pit.
- Add wood ash to the pit, if possible daily. This gives a perceptible odour reduction and might accelerate the elimination of pathogens. Lime also reduces the smell but might slow down the decomposition process.
- Follow closely if the wastewater facilities function properly and do the necessary maintenance on the grease trap (T.B. 4.04).

Key	Input
A. Vertical cut of the simple pit latrine	$L = (n \times b) + 1.4 \text{ m}$ <p>With L: total length of the base n: number of latrine slabs (maximum 6) b: width of a latrine slab (maximum 1 m wide)</p>
B. Excavation for the concrete base	
C. Detail of the base reinforcements	
1. Pit (partly filled with excreta)	- Temporary fencing material
2. Defecation hole	- String line, sticks and tape measure
3. Slab with footrests	- Shovel, pick, miner's bar
4. Cover	- 300 kg/m ³ concrete: +/- 1.3 m ³ per outer 1 m ² cubicle
5. Superstructure	+ +/-0.7 m ³ per extra inner cubicle (latrine battery)
6. Roof	- Reinforcing bars
7. Concrete base	- Tools to prepare and pour concrete
(shallow dugout and inner trench)	- Jute sacking or plastic sheeting
8. Drainage channel	- Corrugated iron sheets to reinforce the pit
(at the sides and back of the latrine)	- Prefabricated slab with cover
9. Aquifer (water table)	- Material and tools for the superstructure and door
10. Mortar layer (at least 10 mm thick)	- Water supply with tap and evacuation system
11. Corrugated iron sheets	- Soap or ash, anal cleansing material (if required)
(pit reinforcement)	- Waste bin for sanitary towels (if required)
12. Example of a slab: concrete, plastic, (wood)	

Dimensions are indicated in m

Remarks

- When choosing the site, ensure that buildings (e.g. health structures) and living areas are not downwind of the latrines.
- Latrines excavated in (unstable) soils have been known to collapse, sometimes resulting in serious accidents. The construction method described above is for a latrine battery accommodating maximum six slabs. It is an assured method for all kinds of loam or clay soils (T.B. 4.05) to prevent (long) rectangular pits from subsiding. Even if the soil would cave in within the pit, the base and the slabs will stay in place, avoiding personal injuries. This design also permits a potential re-excavation of used latrines, if they have been closed for at least two years. Be aware however that the construction method described above isn't suited for sand or loamy sand soils, due to the risk of collapse.
- An alternative for all kinds of soils is the individual circular-shaped pit, which is often more difficult to excavate but less due to collapse because of its natural arching effect. When necessary (certainly for loamy sand and sand soils), the circular pit can be reinforced with one or more concrete rings (T.B. 2.06). Another alternative is to line the rectangular pit completely (T.B. 3.07). For simple pit latrines, it isn't necessary however to put a repartition wall between each latrine compartment. Still other valid construction methods and materials exist, but fall out of the scope of these guidelines. Contact your technical referent for more information, if needed.
- Before the pit can be dug, the depth of the groundwater table has to be determined. In homogeneous soils, the bottom of the pit should be at least 1.5 m above the highest possible groundwater table. The required vertical distance for heterogeneous soils is difficult to predict however.
- The depth of the water table can be estimated by verifying the water level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe in the ground, as deep as 1.5 m beneath the maximum pit depth (2.5 m). When pulled out, the rod or (the earth inside) the pipe should be dry. If not, the pit depth should be adapted accordingly. Soils saturated with water after heavy rainfall might give a false impression of the actual water table level.
- Allow for a spare 0.5 m of depth in the calculation of the pit size to avoid unpleasant sights and excreta splashing out during use. It also permits to cover the excreta in a safe manner when the latrine (battery) is closed down, without causing fly and odour problems. This free space is not part of the effective pit volume. A pit latrine battery constructed with the above method (max. depth of 2.5 m, thus an effective depth of only 2.0 m) will last for about 1.5 to ideally 2 years, if it is used normally by 20 people per compartment (accumulation rate of 0.06 m³/person). Similarly, a single simple pit latrine will last about 5 to 6 years for a family of 5.
- Latrines can be dug in impermeable soils (e.g. clay), but due to the low infiltration rate, they will have to be emptied frequently in a safe manner (T.B. 3.13).
- If the subsoil is very rocky, the area flood prone or the water table high, the pit needs to be constructed partially in the ground (at least 0.5 m deep) and the remaining aboveground part in a very well compacted earth mound. Hence, a specific construction technique will have to be used, as described in T.B. 3.12.
- If it rains a lot in the region, the concrete base can be made a little higher aboveground, for the pit to be less at risk of flooding. An additional mould will be needed to raise the base (foundation) by at least 0.1 m. Be aware that increasing the height of the base will necessitate a considerable amount of concrete.
- The hardening of the concrete base depends on the ambient temperature. The proposed hardening time of 3 days before the pit excavation can be started within the concrete base (whilst keeping it damp) is for temperatures of 20 °C and above. For lower temperatures, it will be necessary to wait longer.

- It is recommended to use concrete (T.B. 3.05) or plastic slabs, certainly for health structures. The use of wooden slabs should be avoided because of aging and termite problems. If used anyway, the wood quality and its impregnation (e.g. with old engine oil against termites) is important. Wooden planks have to be protected with plastic sheeting in order to make their maintenance easier. Slabs of logs should be covered with compacted soil and plastic sheeting. A regular check up of the wooden slabs and their replacement when necessary are essential safety measures.
- In case the superstructure won't be built with masonry-work, some vertical poles can be installed before the concrete base is cast, in order to have attachments for the plastic sheeting, corrugated sheets or local material.
- Separate latrines might be needed for gender purposes. The health structure's staff should always have their own latrines, separated from the patients' and visitors' facilities. Also small children might need their own adapted latrines (T.B. 3.06).
- If there are physically impaired persons amongst the population, the superstructure size of some latrines might have to be adapted. Make also sure to equip these adapted latrines with specific features, such as handrails and a (removable) seat, because some of these physically impaired people will be incapable to squat (section 3.5 Further reading). Don't forget to clean and disinfect these specific features regularly.
- An additional non-transparent screen or wall in front of the entry side of the latrine (battery) improves the privacy, which might lead to a more frequent use of the facility.
- Make sure that correct hand washing facilities with water and soap (or ash) are provided in the direct neighbourhood of the latrines. Latrines for handicapped people (wheelchair) should be provided with washing facilities within the superstructure. Make sure that the wastewater facilities are maintained correctly.
- A waste bin close to the latrines is recommended for the disposal of sanitary towels.
- In some contexts, it might be interesting to integrate the latrines into sanitary blocks, together with personal hygiene facilities like (bucket) showers (T.B. 4.01). In case the women utilise reusable sanitary towels, special washing basins and drying lines could be provided in the female blocks.
- Lighting in and around of the latrines is highly recommended at night for safety / security reasons.
- Insecticide Residual Spraying (T.B. 7.15) of the interior superstructure walls (plastic sheeting included) has potentially a high impact on the fly population.
- When the latrines are nearly full (0.5 m from the slab), move the superstructure and slabs (if possible and if they are still in good condition) to a neighbouring place, after having been disinfected. The old pit can be filled with dry earth mixed with wood ash. In case the concrete base is still in a good condition, it can be re-excavated at least 2 years after the latrine (battery) has been closed. However, the corrugated iron sheets should be replaced as they will be (partly) corroded. If the latrines are demolished, water-absorbing trees (e.g. mangos) can be planted inside the filled pit to re-stabilize the underground.
- Ventilated Improved Pit (T.B. 3.07) and twin pit latrines (T.B. 3.09) can also be chosen, but they are more suited for stabilised situations, and certainly recommended for health structures.
- In the first phase of the latrines project, the recommended ratio of 1 latrine per 20 persons might not immediately be attainable, because of the time it takes to construct them.

T.B. 3.05 Latrine slab

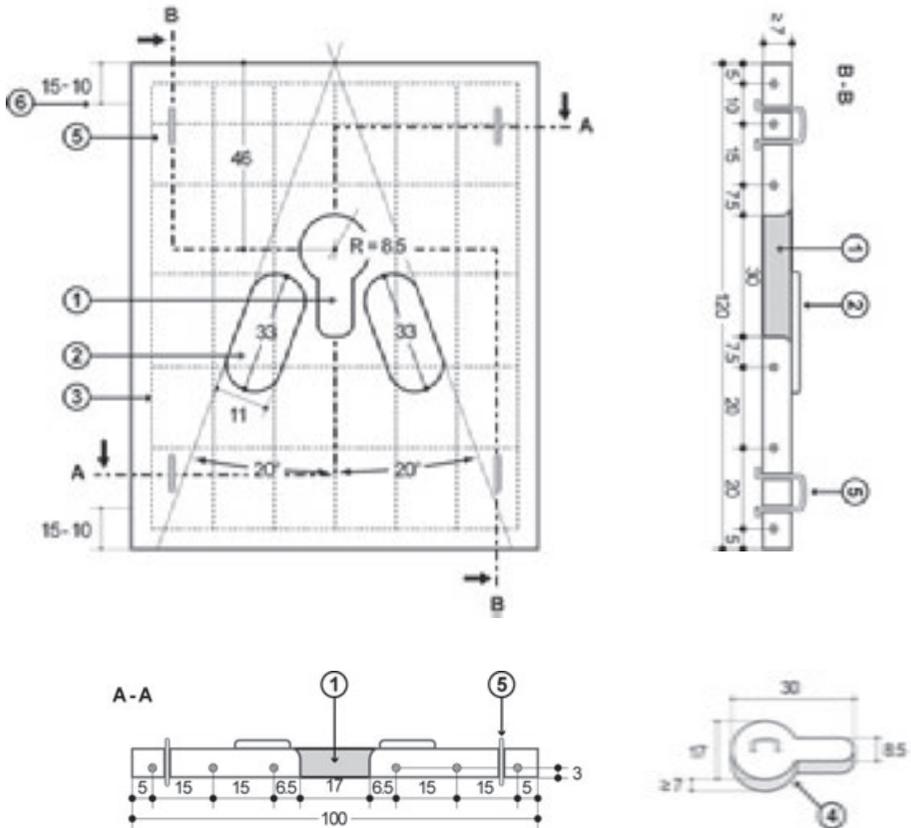
An appropriate latrine slab is an essential component of a latrine for safety, ease of use and maintenance. Reinforced concrete slabs can meet these criteria and are easy to make for a relatively low cost.

Construction

- Make a metal or wooden mould with internal dimensions that are adapted to the slab size, and a wooden or metal template for the defecation hole.
- Place the mould on a flat surface covered by a layer of sand, plastic sheeting or paper.
- Cut the iron reinforcing bars to length with a hacksaw or cutting pliers and join them with metal wire (as per figure). Make 4 handles; per handle, bend a piece of re-bar in a U-shape integrating 2 pieces of pipe.
- Coat the inside of the mould and the contact surface of the template with an oily product such as used engine oil, to avoid that the concrete would stick to them.
- Place the reinforcing bars on spacers of about 2.5 - 3 cm high within the mould. Install also the 4 handles at the slab corners, making sure that their integrated pipes will be imbedded in the concrete.
- Put the template in the mould on its correct position (as per figure).
- Prepare concrete of 300 kg/m³ (T.B. 2.05).
- Pour the concrete, and vibrate it by tapping with a hammer on the sides of the mould.
- Position immediately the foot rests (e.g. made of bricks) as per figure.
- Sprinkle some cement directly on the wet concrete and polish the surface. Finalize the slab by making sloped curves around the defecation hole and footrests (useful when cleaning the slab).
- Cover the slab with plastic sheeting or jute sacking and sprinkle it twice per day with water to keep it damp during the curing period.
- Remove the mould and the template after 24 hours, recover the slab with the plastic sheeting or jute sack and keep damp.
- Wait for 7 days of curing in the shade for the concrete to gain strength, before installing the slab on the pit.
- Prepare a lid (e.g. wood, plastic or concrete) with a handle to cover the defecation hole.

Remarks

- If embarking on a programme of latrine construction, it is well worth the trouble to build a workshop for continuous slab production. This workshop should have a water point, a storage for tools and a covered area for casting and curing the slabs.
- The size of the slab has to be adapted to the pit size. However, for safety and practical reasons (slab weight), it is strongly recommended to use the slab dimensions as proposed in the figure and to adapt the pit size to the slab (T.B. 3.04). Be aware during the pit construction that the concrete slab should extend at least 10 cm beyond each side of the latrine support to ensure a secure seating.
- For a small number of slabs to be produced, the mould can also be replaced by a shallow excavation in the ground, covered with plastic sheeting. The dimensions stay the same.
- The template for the defecation hole should be tapered to ease its withdrawal from the concrete.
- Don't forget the handles as it is very difficult to move the slab without them. The figures suggests handles that sink into the slab once it's installed. This reduces the risk of people tripping over them and eases the construction of the superstructure. Make sure the handles fall inside the lines indicating the overlap with the pit's lining. Simple handles imbedded in the concrete can do as well.
- The footrests are important for the user to position himself correctly over the defecation hole (certainly at night).
- The dimensions of the drop hole and the footrests must be adapted for small children (T.B. 3.06).
- If possible, make a gentle and smooth slope over the complete slab surface towards the defecation hole; this will avoid stagnant liquids and will ease its cleaning.
- Take care of the curing (7 days in the shade, kept damp): it greatly affects the strength of the slab.



Key

1. Defecation hole
2. Footrests
3. 8 mm iron reinforcement bars
4. Template for defecation hole (tapered)
5. Handles to ease the transport of the slab
6. Lines indicating the overlap with latrine support / lining (at least 10 cm)

Dimensions are in cm

Input

- Cement: 1/2 of a 50 kg bag
- Sand: about 35 l
- Gravel: about 70 l
- Potable water (clean, non-salty)
- Shuttering timber, height min. 70 mm: about 5 m
- Saw, hammer and nails
- Reinforcement bars, diameter min. 6 mm: 14 m
- Hacksaw or iron bar cutting pliers and pincers
- Wire for joining reinforcement bars
- Tape measure
- Shovel and bucket
- Trough or board for mixing concrete
- Trowel, float
- Bricks for the foot rests
- Pieces of (plastic) pipe
- Template

T.B. 3.06 Children's pit latrines

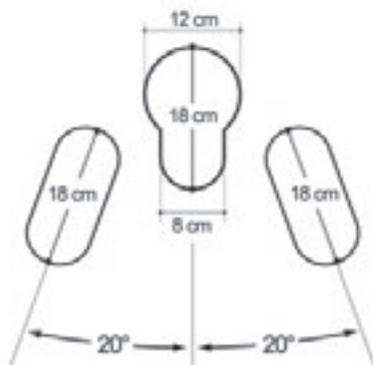
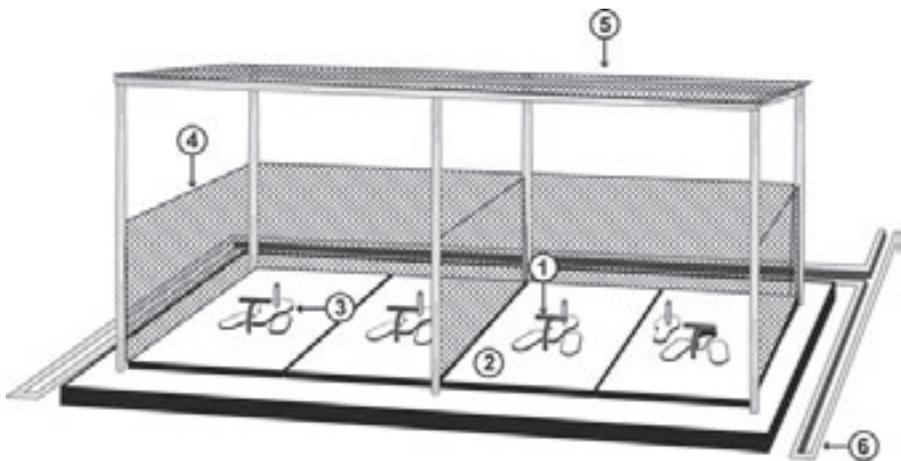
Small children might have problems using normal pit latrines because of the big size of the drop hole and the position of the foot rests. They are often scared inside the closed superstructure of a normal pit latrine as well. The children's pit latrines are therefore an answer to these problems. If well designed and built, correctly sited and well maintained, they contribute significantly to the prevention of faeco-oral diseases.

Construction

- Choose a site at least 30 m away (more for fissured underground and limestone) and downhill from all water sources, storage and treatment facilities. The latrine (battery) must have easy access, not less than 5 m and not more than 50 m away from the dwellings (< 30 m from buildings within a health structure).
- Prepare the site for construction: remove all debris, flatten the surface, put up a temporary fence, implement soil texture and permeability tests (T.B. 4.05), determine the depth of the water table and bring in the needed material and equipment.
- Prepare, excavate and line the pit in a similar way as described for a simple pit (T.B. 3.04) or a VIP (T.B. 3.07) latrine battery, depending on the soil type and the skills of the mason. In case the VIP latrine lining is chosen, it isn't necessary to put a closed separation wall in between each compartment, thus it's only required to construct the foundation circumference. The layer of lean concrete for stabilisation on the bottom of the pit is highly recommended however.
- Make slabs (T.B. 3.05 or 3.08), depending on the type of lining that has been chosen), but adapted to the size of the children: a smaller defecation hole including a matching lid, footrests that are closer together and an integrated handlebar, so that they can hold themselves in balance when they are squatting. The ventilation pipe opening in the "VIP" slabs (T.B. 3.08) isn't needed for children's pit latrines.
- Install the prefabricated slabs (with cover) on the latrines' base, once it has settled for at least 3 days. To ensure a secure seating, the slab should be fixed to its base (overlaps of at least 0.1 m) with a 10 mm thick mortar layer (T.B. 2.05).
- Construct a superstructure around the slabs that is large enough for the attendants to be able to walk around the child during defecation (e.g. one open superstructure for two slabs). It may be built with masonry-work, wood or plastic sheeting, but preferably local materials (e.g. branches and mud) as long as this doesn't have a too negative impact on the environment (e.g. deforestation). The superstructure can be open at the front in order to have more light coming in, and the child not to feel imprisoned in a rather small cubicle.
- Fix a roof with the slope towards the back of the structure, away from the entrance.
- Make a drainage channel at the back and the sides of the latrines to prevent runoff water entering the pit and creating erosion of its walls.
- Provide correct hand washing facilities in the direct neighbourhood of the latrines. Make sure that a grease trap (T.B. 4.04) and an infiltration system (T.B. 4.06; 4.07; 4.08) are foreseen.

Operation and Maintenance

- Provide water and soap (or ash), and anal cleansing material if required (certainly in health structures).
- Try to ensure that the cover is always replaced on the defecation hole to reduce the breeding of flies and to lessen bad odours in and around the latrines' open superstructure.
- Try to have the slabs and surroundings cleaned / disinfected on a daily basis. Don't forget to clean and disinfect the handlebars. Never put disinfectants (e.g. chlorine products) or any other chemicals in the pit as they might inhibit the natural decomposition of the faecal material. It is only permitted during an epidemic of highly infectious diseases (e.g. cholera, Viral Haemorrhagic Fevers) to pour disinfectants or human wastes mixed with a (strong) chlorine solution into a latrine pit.
- Add wood ash to the pit, if possible daily. This gives a perceptible odour reduction and might accelerate the elimination of pathogens. Active lime will also reduce the smell but might slow down the decomposition process of the faeces.
- Follow closely if the wastewater facilities function properly and do the necessary maintenance on the grease trap (T.B. 4.04).



Key

1. Handle bar (for a child to hold on to when squatting)
2. Slab with adapted footrests
3. Defecation holes (adapted size for children) with lid
4. Open superstructure
5. Roof
6. Drainage channel

Input

- Temporary fencing material
- Tape measure, string line and sticks
- Shovel, hoe, pick, miner's bar
- Fired bricks or cement blocks / 300kg/m³ concrete
- Reinforcing bars (8 mm)
- Tools to prepare and cast concrete
- Jute sacking or plastic sheeting
- Prefabricated slab (adapted for children) with cover
- Material and tools for the superstructure
- Water supply with tap and evacuation system
- Soap or ashes
- Anal cleansing material (if required)

Figure shows children's latrines on a concrete base (as per T.B. 3.04). It can also be installed on a complete lining (T.B. 3.07), depending on the soil conditions and/or the skills of the mason.

Dimensions (in cm) are indicative and have to be adapted according to the context.

Remarks

- When choosing the site, ensure that buildings (e.g. health structures) and living areas are not downwind of the children's latrines.
- Before the pit can be dug, the groundwater table level has to be determined. In homogeneous soils, the bottom of the pit should be at least 1.5 m above the highest possible groundwater table. The required vertical distance for heterogeneous soils is difficult to predict however.
- The depth of the water table can be estimated by verifying the water level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe in the ground, as deep as 1.5 m beneath the required pit depth. When pulled out, the rod or (the earth inside) the pipe should be dry. If not, the pit depth should be adapted accordingly. Soils saturated with water after heavy rainfall might give a false impression of the actual water table level.
- Allow for a spare 0.5 m of depth in the calculation of the pit size to avoid unpleasant sights and excreta splashing out during use. It also permits to cover the excreta in a safe manner when the latrine (battery) is closed down, without causing fly and odour problems. The spare space is not part of the effective pit volume. This means for instance that a pit with a maximum depth of 2 m (thus an effective depth of only 1.5 m) will only last for about 2 years if it is used normally by 20 children (accumulation rate of 0.04 m³/child).
- An alternative construction method is the individual circular-shaped pit, which is often more difficult to excavate but less due to collapse because of its natural arching effect. When necessary, the circular pit can be reinforced with one or more concrete rings (T.B. 2.06). Other valid construction methods and materials exist for (circular) latrine pits, but fall out of the scope of these guidelines. Contact your technical referent for more information, if needed.
- If the subsoil is very rocky, the area flood prone or the water table high, the pit needs to be constructed partially in the ground (at least 0.5 m deep) and the remaining aboveground part in a very well compacted earth mound. Hence, a specific construction technique will have to be used, as described in T.B. 3.12.
- It is recommended to use concrete slabs (T.B. 3.05, 3.07), certainly for health structures. The use of wooden slabs should be avoided if possible because of aging and termite problems. If used anyway, the wood quality and its impregnation (with old engine oil against termites) is important. Wooden planks have to be protected with plastic sheeting to make the maintenance easier. Slabs of logs should be covered with compacted soil and plastic sheeting. A regular check up of the wooden slabs and their replacement when necessary are essential safety measures.
- In case the superstructure won't be built with masonry-work, some vertical poles can be installed before the concrete base (T.B. 3.04) is cast, in order to have attachments for the plastic sheeting, corrugated sheets or local material.
- As the superstructure is completely open for children's latrines, it is impossible to create some darkness inside the cubicles, and therefore the VIP fly trap principle (T.B. 3.07) won't work. The open superstructure also results in the need for lids, so the VIP ventilation principle won't work either, meaning that ventilation pipes aren't necessary at all.
- If there are physically impaired children, make sure to equip some latrines with specific features, such as handrails and a (removable) seat because some of them will be incapable to squat (section 3.5 Further reading). It's even advised to provide all children's latrines with handles.
- Lighting in and around the children's latrines is highly recommended for safety / security reasons.
- Insecticide Residual Spraying (T.B. 7.15) of the interior superstructure walls (plastic sheeting included) has potentially a high impact on the fly population.
- When the children's latrines are nearly full (0.5 m from the slab), move the superstructure and slabs (if possible and if they are still in good condition) to a new pit, after having been disinfected. The old pit can be filled with dry earth mixed with wood ash. In case the base is still in good state, it can be re-excavated after at least 2 years. If the latrines are demolished, water-absorbing trees (e.g. mangos) can be planted inside the pit to re-stabilize the underground.
- In the first phase of the latrines project, the aim to have a ratio of 1 latrine per 20 children might not immediately be attainable.
- Potties can (sometimes) be an acceptable alternative to children's pit latrines. They need to be emptied and cleaned after each use.

T.B. 3.07 Ventilated Improved Pit (V.I.P.) latrines

The VIP latrine outclasses the simple pit latrine by some particular features. The VIP latrine uses the air movement across its ventilation pipe to draw gasses out of the pit, and thus to produce fewer odour nuisances. Flies trying to leave the pit are attracted towards the light at the top of the ventilation pipe, but as they fail to escape due to its screen, they die. This makes of the VIP latrine a good fly trap as well.

Construction

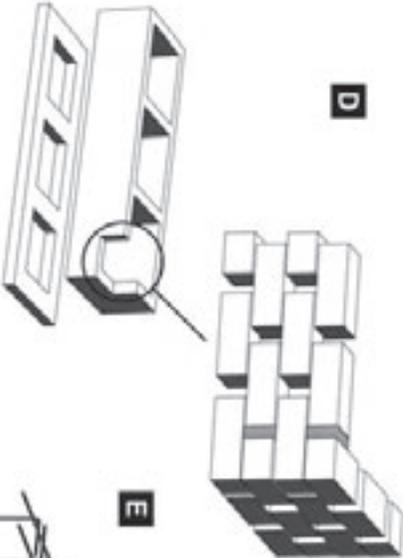
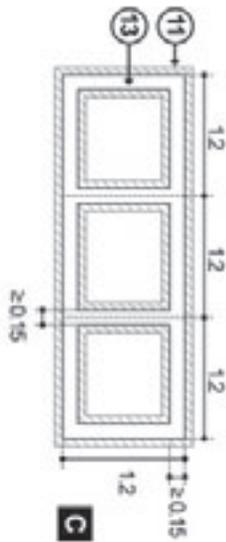
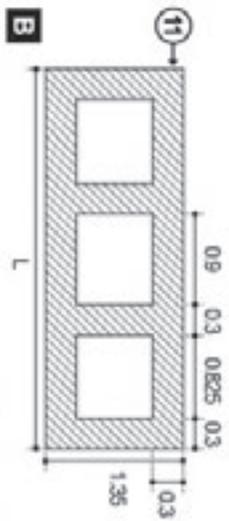
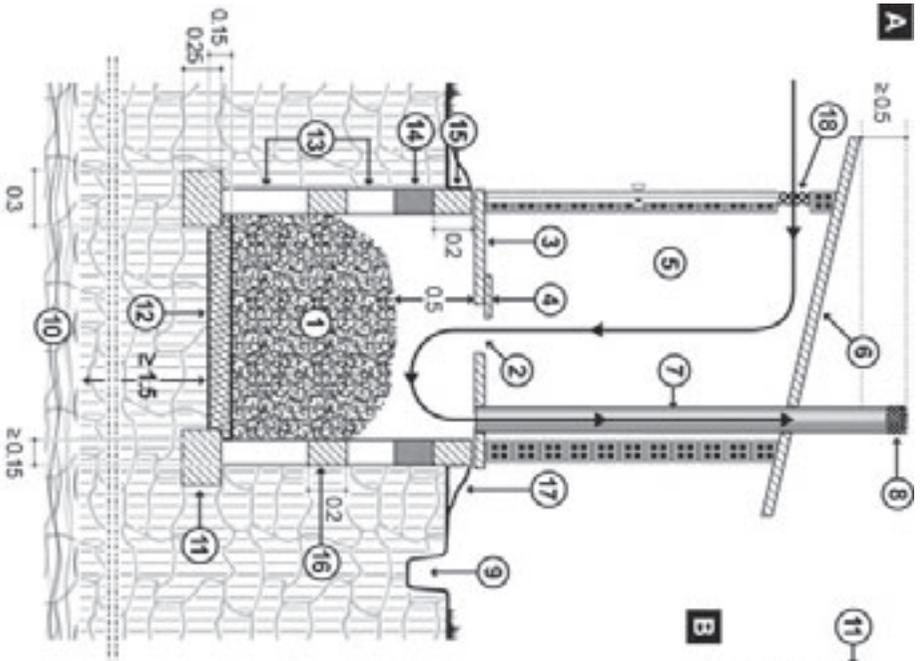
- Determine the effective pit volume, which is depending on the number of potential users, the accumulation rate and the desired lifetime of the latrine (section 3.4.6). If standardised VIP slabs (T.B. 3.08) with fixed dimensions are used for a latrine battery with a certain total volume, only the required depth, including the 0.5 m needed for the free space, should be determined.
- Choose a site at least 30 m away (more for fissured underground and limestone) and downhill from all water sources, storage and treatment facilities. The VIP latrine (battery) must have easy access, not less than 5 m and not more than 50 m away from the dwellings (< 30 m from buildings within a health structure).
- Prepare the site for construction: remove all debris, flatten the surface, put up a temporary fence, implement soil texture and permeability tests (T.B. 4.05), determine the depth of the water table and bring in the needed material and equipment.
- Lay out the excavation area according to the outer dimensions of the foundation as per figure B, using string lines. To ease the construction works afterwards, the lay out of the excavation area can be made slightly bigger. For unconsolidated (e.g. sandy) soils, it might be necessary to dig conical walls to avoid collapse.
- Excavate the pit. The bottom of the pit should be at least 1.5 m above the highest possible water table.
- Dig within the excavated pit a trench system of 0.25 m deep as per figure B.
- Prepare and install some reinforcing bars inside the trench system. Make sure that the reinforcing bars stay at least 30 mm away from the sides and bottom of the trench system (use spacers).
- Pour concrete (300 kg/m³; T.B. 2.05) inside the trench system to form the pit's foundation. Vibrate the concrete to remove all the air. Keep the concrete moist for a week with plastic sheeting or jute sacking that needs to be wetted twice a day.
- Dig another 0.05 m of soil within the foundation compartments, after the concrete has settled.
- Build on top of the foundation, which has hardened for at least 3 days, the open-jointed (honeycombed) lining and the sealed (closed) partition walls that divide the pit into different compartments (as per figure C). The lining and partition walls, erected in cement blocks or a double layer of fired bricks, should overlap correctly in all the corners (as per figure D) to be able to resist the ground pressure.
- Build a sealed lining with cement blocks or a double layer of fired bricks on top of the open-jointed lining and partition walls.
- Prepare on top of the lining and partition walls the casing for the reinforced concrete ring beam.
- Prepare and install every 0.2 m the required reinforcing bars inside the casing (as per figure E). Make sure that the reinforcing bars stay at least 25 mm away from the sides of the casing (use spacers).
- Pour the concrete (300 kg/m³) inside the casing, while tapping gently on its sides. The concrete can also be vibrated by poking it with a reinforcing bar. Keep the concrete moist for a week to ensure correct curing.
- Pour a layer of lean concrete (150 kg/m³; T.B. 2.05) at the bottom of the pit. It will give extra support to the lining. Keep this concrete moist and cover the whole pit with plastic sheeting.
- Install prefabricated VIP slabs (T.B. 3.08) on the ring beam that has hardened for at least 3 days. To ensure a secure seating, every slab should have a good overlap over its entire circumference with the lining and partition walls (respectively 0.15 and 0.075 m) and be fixed with a 10 mm thick mortar layer.
- Backfill the space in between the pit lining and the excavated hole with gravel (honeycombed part) and compacted soil (sealed part and concrete ring beam).
- Add an impermeable layer (mortar or clay) against the aboveground part of the ring beam.
- Construct a superstructure on top of the slabs, adapted to local preferences. It may be built with masonry-work, wood or local materials. Plastic sheeting is not appropriate as it might not provide enough darkness for the VIP principle to work (flies being attracted by light only entering via the vent pipe).
- Fit a roof to the superstructure with its slope carrying rainwater towards the back of the latrines.

- Fix a plastic ventilation pipe with a diameter of 150 mm to each slab and secure it to the superstructure. Put some mortar around the pipes where they pass through the roof.
- Fit corrosion / UV-resistant screens at the pipes' top and above the doors to avoid the entry and exit of flies.
- Make a drainage channel at the back and the sides of the latrines to lead the runoff water away.

Key	Input
A. Vertical cut of the VIP latrine	
B. Dimensions of the foundation (example for 3 compartments)	
C. Dimensions of the lining and partition walls	
D. Detail of the masonry overlap in a lining corner	
E. Detail of the ring beam reinforcement	
1. Effective pit volume (filled)	- Temporary fencing material
2. Defecation or squatting hole without cover	- String line, sticks and tape measure
3. Slab	- Shovels, picks, miner's bars
4. Footrests	- Sand, cement, gravel and clean water
5. Superstructure (semi-dark inside)	- Reinforcing bars
6. Roof	- Tools to prepare and cast concrete
7. Ventilation pipe	- Jute sacking or plastic sheeting
(internal size depending on material used)	- Fired bricks or cement blocks
8. Fly screen	- Masons tools
(corrosion and UV-resistant material)	- Prefabricated VIP slabs
9. Drainage channel at the sides and back of latrine	- Material and tools to build the superstructure
10. Aquifer (water table)	- PVC pipe (preferably diameter of 150 mm)
11. Reinforced concrete foundation	- Screen (e.g. mosquito netting)
12. Lean concrete for stabilisation (optional)	- Experienced mason and 1 or 2 labourers
13. Open-jointed (honeycombed) lining	- Water supply with tap and evacuation system
14. Sealed (closed) lining	- Soap or ash, anal cleansing material (if required)
15. Reinforced concrete ring beam	- Waste bin for sanitary towels (if required)
16. Intermediate reinforced concrete ring beam	
(depending on the height of the lining (> 3 m deep)	
and the stability of the soil)	
17. Impermeable layer	With $L = (n \times b) + 0.15m$
18. Air and light inlet covered with mosquito netting	L: total length of the foundation
(only one, area = at least 3 times the vent section)	n: number of slabs (max. 6)
	b: width of a slab
	Dimensions are indicated in m

Operation and Maintenance

- Do not use a cover on the defecation hole of a VIP latrine as this would stop the air circulation needed for the ventilation.
- Make sure water and soap (or ash) are always available at the nearby hand washing point.
- Provide anal cleansing material if required (certainly in health structures).
- Try to have the slabs and surroundings cleaned on a daily basis. Never put disinfectants (e.g. chlorine products) or any other chemicals in the pits as they might inhibit the natural decomposition of the faecal material. It is only permitted during an epidemic of highly infectious diseases (e.g. cholera, Viral Haemorrhagic Fevers) to pour disinfectants or human wastes mixed with a (strong) chlorine solution into a latrine pit.
- Add wood ash to the pit, if possible daily. This reduces the odours even more and might accelerate the elimination of pathogens. Lime also reduces the smell but might slow down the decomposition process.
- Pour once in a while a bucket of water through the vent pipes to remove spider webs and flies corpses that could block the ventilation. Check also if the screens on top of the ventilation pipes and above the doors are still intact and replace them when necessary.



Remarks

- When choosing the site, ensure that buildings (e.g. health structures) and living areas are not downwind of the VIP latrines. VIP latrines should also be built on an open space, away from trees, buildings or other objects that could impede air movement.
- Latrines excavated in (unstable) soils have been known to collapse, sometimes resulting in serious accidents. The construction method described above is for latrine batteries accommodating up to 6 standard VIP slabs (T.B. 3.08), with a maximum pit depth of 3 m. It is an assured method for all kinds of soils to prevent (long) rectangular pits from collapsing. For pits exceeding 3 m depth, it is recommended to cast an intermediate ring beam halfway the height of the lining.
- Allow for a spare 0.5 m of depth in the calculation of the pit size to avoid unpleasant sights and excreta splashing out during use. It also permits to cover the excreta in a safe manner when the latrine (battery) is closed down, without causing fly and odour problems. This free space is not part of the effective pit volume.
- Before the pit can be dug, the depth of the groundwater table has to be determined. In homogeneous soils, the bottom of the pit should be at least 1.5 m above the highest possible groundwater table. The required vertical distance for heterogeneous soils is difficult to predict however.
- The depth of the water table can be estimated by verifying the water level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe in the ground, as deep as 1.5 m beneath the required depth. When pulled out, the rod or (the earth inside) the pipe should be dry. If not, the pit depth should be adapted accordingly. Soils saturated with water after heavy rainfall might give a false impression of the actual water table level.
- Single VIP latrines can also be built with the method described above. An alternative is the individual circular-shaped pit, which is often more difficult to excavate but less prone to collapse because of its natural arching effect. When necessary, the circular pit could be reinforced with one or more concrete rings (T.B. 2.06). Still other valid construction methods and materials exist, but fall out of the scope of these guidelines. Contact your technical referent for more information, if needed.
- VIP latrines can be dug in impermeable soils (e.g. clay), but due to the low infiltration rate, they will have to be emptied frequently in a safe manner (T.B. 3.13).
- In case the soil is unstable, the pit will need to be supported with struts during the works or be excavated conically.
- If the subsoil is very rocky, the area flood prone or the water table high, the method described above can be adapted with the pit partially constructed underground (at least 0.5 m deep) and the remaining aboveground part in a very well compacted earth mound (T.B. 3.12).
- The hardening of the concrete elements depends on the ambient temperature. The proposed hardening time of 3 days before the construction can continue on the concrete elements (whilst keeping them damp) is for temperatures of 20 °C and above. For lower temperatures, it will be necessary to wait longer.
- The door of a VIP superstructure should be self-closing. Above each door should be an air hole for ventilation purposes. This air hole should have a surface at least three times larger than the cross sectional area of the ventilation pipe, and be covered with a screen (mosquito netting).
- If it is acceptable to the population, the superstructure of a single or double VIP latrine can also be made in a spiral form without a door. This still provides enough darkness inside for the VIP principle to work.
- The separation in individual compartments by solid walls going from the bottom until the top of the pit is needed to avoid shortcuts of the air movement between the different defecation holes, which would hamper the VIP ventilation principle. This means as well that every single compartment of the VIP latrine battery should have its own ventilation pipe.

- Each ventilation pipe should be vertical, sticking out above the latrine's roof by at least 0.5 m (as per figure A). The hole where the vent pipe comes through the roof should be made watertight to avoid leaks. The pipe should also be flush with the slab's underside. To ensure a better anchorage of the plastic vent pipe at the bottom, a clamp can be connected at the level where it will be mortared in the slab. An alternative is to provide the VIP latrine slab already with a short piece of pipe (spigot), being anchored in the concrete. It should be flush with the underside of the slab and sticking out above by at least 0.1 m. Once the slab is installed, the vent pipe can be slit over the spigot. This spigot facilitates the construction, but makes the transport of the slab more difficult (without breaking the spigot).
- When PVC pipes are used as a vent pipe, their diameter should ideally be 150 mm, and at least 110 mm. Having a dark coloured plastic vent pipe at the outside of the superstructure and oriented towards the sun might allow a better ventilation of the VIP latrine during wind still days, but complicates the construction.
- Instead of a round plastic vent pipe, local alternatives such as reeds or bricks covered with earth plaster have been used already as well. When bricks are used for the vent pipe, its form will be square with internal dimensions of at least 225 mm x 225 mm, because their rougher surface (still preferably plastered) hinders the airflow. The size of the hole in the latrine slab should be adapted accordingly.
- The fly screen on the top of the vent pipe must be in stainless steel, aluminium or PVC coated fibreglass, because the gasses escaping from the latrine are very corrosive to mild metal. Stainless steel seems to be the best but also the most expensive material for the screen, while aluminium seems to be the best quality/prize option. If really nothing else is available, painted metal mesh is the last option.
- Separate VIP latrines might be needed for gender purposes. The health structure's staff should always have their own latrines, separated from the patients' and visitors' latrines. VIP latrines are not really suited for small children; therefore special children's latrines might have to be built (T.B. 3.06).
- If there are physically impaired persons, the size of the superstructure of some VIP latrines might have to be adapted. Make also sure to equip these adapted VIP latrines with specific features, such as handrails and a (removable) seat, because some of these physically impaired people will be incapable of squatting (section 3.5 Further reading). Don't forget to clean and disinfect these specific features regularly.
- An additional non-transparent screen or wall in front of the entry side of the VIP latrine (battery) improves the privacy, which might lead to a more frequent use of the facility. However, this screen / wall should not impede the air circulation needed for the VIP principle to work.
- Make sure that correct hand washing facilities with water and soap (or ash) are provided in the direct neighbourhood of the VIP latrines. VIP latrines for handicapped people (wheelchair) should be provided with washing facilities within the superstructure. Make sure that the wastewater facilities are maintained correctly.
- A waste bin close to the VIP latrines is recommended for the disposal of sanitary towels.
- In some contexts, it might also be interesting to integrate the VIP latrines into sanitary blocks, together with personal hygiene facilities like (bucket) showers (T.B. 4.01). In case the women utilise reusable sanitary towels, special washing basins with drying lines could be provided in the female blocks.
- Outside lights around the VIP latrines are highly recommended for safety / security reasons.
- Insecticide Residual Spraying (T.B. 7.15) of the VIP latrines' interior superstructure walls has potentially a high impact on the fly population.
- When the pit is nearly full (0.5 m from the slab), close it down by filling the pit with dry earth mixed with wood ash. Since VIP latrines demand a considerable investment, it should be checked first if they can be emptied in a correct way (T.B. 3.13). With the complete lining, the pit is less at risk of collapse, so water can be added to render the sludge more liquid. However, do not empty VIP latrines manually for at least two years. Twin pit latrines (T.B. 3.09) could be considered as an alternative. If the VIP latrines are demolished, water absorbing trees (e.g. mangos) can be planted in the pit to re-stabilize the underground.

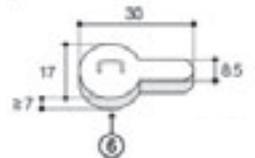
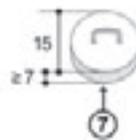
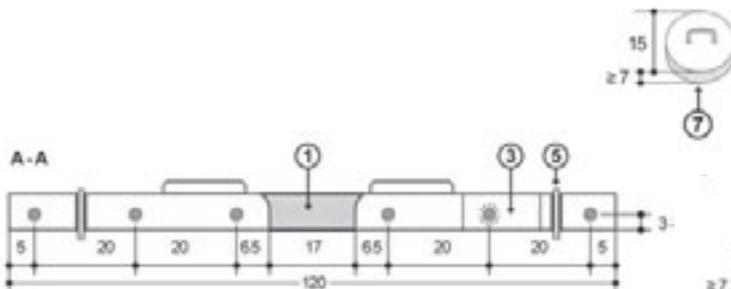
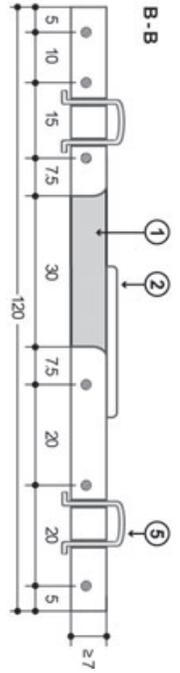
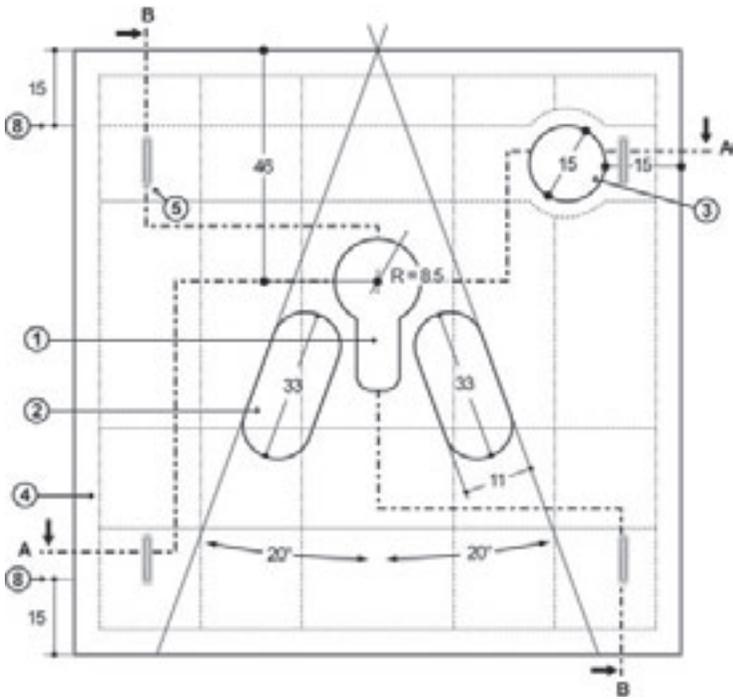
T.B. 3.08 V.I.P. latrine slab

An appropriate VIP latrine slab is an essential component of a VIP latrine for safety, ease of use and maintenance. Reinforced concrete slabs can meet these criteria and are easy to make for a relatively low cost.

Construction

- Make a metal or wooden mould with internal dimensions that are adapted to the slab size, and wooden or metal templates for the defecation and ventilation pipe holes.
- Place the mould on a flat surface covered by a layer of sand, plastic sheeting or paper.
- Cut the iron reinforcing bars to length with a hacksaw or cutting pliers and join them with metal wire (as per figure). Make 4 handles; per handle, bend a piece of re-bar in a U-shape integrating 2 pieces of pipe.
- Coat the inside of the mould and the contact surface of the templates with an oily product such as used engine oil, to avoid that the concrete would stick to them.
- Place the reinforcing bars on spacers of 2.5 - 3 cm high within the mould. Install also the 4 handles at the slab corners, making sure that their integrated pipes will be imbedded in the concrete.
- Put the templates in the mould on their correct position (as per figure).
- Prepare concrete of 300 kg/m³ (T.B. 2.05).
- Pour the concrete, and vibrate it by tapping with a hammer on the sides of the mould.
- Position immediately the foot rests (e.g. made of bricks).
- Sprinkle some cement directly on the wet concrete and polish the surface, and finalize the slab by making sloped curves around the defecation hole and footrests (useful when cleaning the slab).
- Cover the slab with plastic sheeting or jute sacking and sprinkle it twice per day with water to keep it damp during the curing period.
- Remove the mould and the templates after 24 hours, recover the slab with the plastic sheeting or jute sack and keep damp.
- Wait for 7 days of curing in the shade for the concrete to gain strength before installing the slab on the pit.

Key	Input
1. Defecation hole (without cover)	- Cement: 3/5 of a 50 kg bag
2. Footrests	- Sand: about 42 l
3. Ventilation pipe hole	- Gravel: about 84 l
4. 8 mm iron reinforcing bars	- Potable water (clean, non-salty)
5. Handles to ease the transport of the slab	- Shuttering timber, height min. 70 mm: about 5 m
6. Template for the defecation hole (tapered)	- Saw, hammer and nails
7. Template for the ventilation pipe hole (tapered)	- Reinforcing bars, diameter min.6 mm: about 15 m
8. Lines indicating the overlap with the pit's lining	- Hacksaw or iron bar cutting pliers and pincers
	- Wire for joining reinforcing bars
Dimensions are in cm	- Tape measure
	- Shovel and bucket
	- Trough or board for mixing concrete
	- Trowel, float
	- Bricks for the foot rests
	- Pieces of (plastic) pipe
	- Templates



Remarks

- If embarking on a programme of latrines' construction, it is well worth the trouble to build a workshop for continuous slab production. This workshop should have a water point, a storage for tools and a covered area for casting and curing the slabs.
- The size of the slab has to be adapted to the pit size. However, for safety and practical reasons (slab weight), it is strongly recommended to use the slab dimensions as proposed in the figure and to adapt the size of the pit accordingly (T.B. 3.07). Be aware that the slab should extend 15 cm beyond each side of the lining to ensure a secure seating. When several VIP slabs are positioned next to each other, they should rest correctly on the pit's repartition walls by at least 7.5 cm. The slabs should be mortared to their supporting walls to avoid air movement shortcuts between the defecation holes and to deny access to flies and other vectors.
- For a small number of slabs to be produced, the mould can also be replaced by a shallow excavation in the ground, covered with plastic sheeting. The dimensions stay the same.
- Don't forget the handles. It is very difficult to move the slab without them. The figures suggests handles that sink into the slab once it's installed. This reduces the risk of people tripping over them and eases the construction of the superstructure. Make sure the handles fall inside the lines indicating the overlap with the pit's lining. Simple handles imbedded in the concrete can do as well.
- Don't forget the hole for the ventilation pipe (preferably a diameter of 15 cm for plastic pipes), as far away as possible from the defecation hole (at least 30 cm), but free from the sides where the slab will be seated on the supporting pit walls. An alternative is to integrate immediately a spigot (plastic pipe sticking out by at least 0.1 m on top of the slab, but flush with its underside) on which the vent pipe will be installed later.
- The templates for the defecation and the ventilation pipe holes should be tapered to ease their withdrawal from the concrete.
- The footrests are vital for the user to position himself correctly over the defecation hole (certainly at night).
- If the slab is used for children's latrines, the dimensions of the drop hole and the footrests must be adapted (T.B. 3.06), and the vent pipe hole isn't necessary, because the VIP principle won't work anyway with the open superstructure.
- If possible, make a gentle and smooth slope over the complete slab surface towards the defecation hole; this will avoid stagnant liquids and will ease its cleaning.
- Take care of the curing (7 days in the shade, kept damp): it greatly affects the strength of the slab.

T.B. 3.09 Twin pit latrine

Twin pit latrines may be used where toilets have to last for a long time (e.g. for public places, health structures), so as to economise space and money in the long run. They also produce a good quality soil conditioner. The latrine is built on an open lined pit divided in two by a closed partition wall. As both pits are used in alternation, they can be emptied safely and reused. The system is thus permanent and especially suited for stabilized situations. For collective facilities, several pits may be constructed in series.

Construction

The construction of a twin pit latrine is very similar to a VIP latrine battery (T.B. 3.07) with two compartments, but its design has some specific features, as described below:

- Each individual pit should have enough storage capacity to last for at least two years.
- To permit easy access to each pit during the emptying procedure, their dimensions have to be adapted. The suggested outer dimensions for the lining of the complete twin pit latrine are 2.4 m x 2.0 m, if this would permit to have the bottom of the pit still 1.5 m above the highest possible water table (taking into account the accumulation rate and the free space of 0.5 m for backfilling; section 3.4.6). For these lining measurements, the outer dimensions of the foundation should be 2.55 m x 2.15 m. The ring beam should include a central beam, which can carry standard size latrine slabs.
- Standard size slabs (T.B. 3.05) can be used if the ventilation pipe is located outside the superstructure. An alternative is to cast a big slab in situ over the whole area where the superstructure will be constructed.
- Per twin pit latrine, 8 small reinforced concrete slabs should be cast (for the suggested lining dimensions: each slab should be 1.0 m x 0.3 m):
 - 6 plain slabs with handles at their sides.
 - 2 slabs with a ventilation hole according to the available vent pipe (ideally a PVC pipe with a diameter of 150 mm, or at least 110 mm).
 - The slabs will have to be mortared at the back of the lining.
 - The ventilation pipes will have to be anchored to the outside of the superstructure to avoid being blown over by heavy winds. A dark colour of the ventilation pipes will help the airflow during wind still days, if the pipes are oriented towards the sun.

Operation

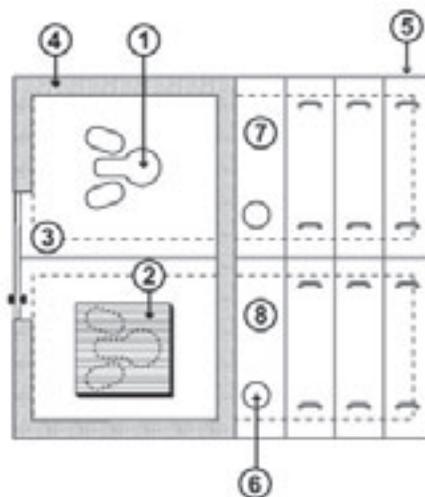
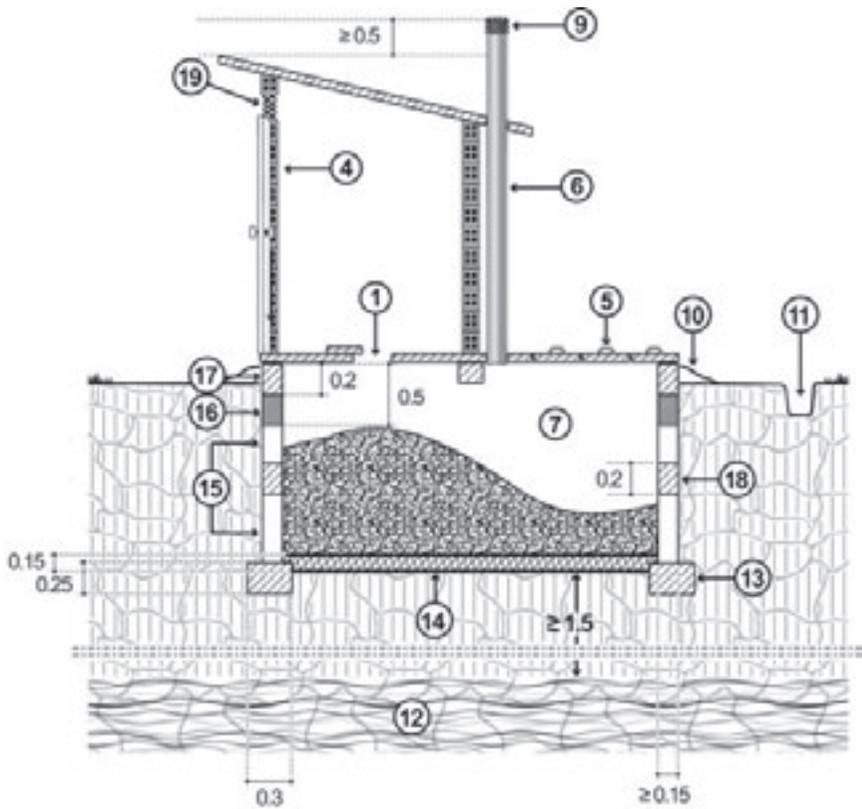
After a period of at least 2 years, the first pit will be full (filled to 0.5 m underneath the slab):

- Fill the first hole with a mixture of wood ash and dry earth.
- Block its defecation hole with a cover fixed by a thin layer of mortar.
- Open the second pit.

After a further period of at least two years, the second pit will be full (filled to 0.5 m under the slab):

- Fill the second hole with a mixture of wood ash and dry earth.
- Block its defecation hole with a cover fixed by a thin layer of mortar.
- Open the small rectangular slabs of the first pit.
- Take out the contents of the first pit, which has transformed into harmless matter ("compost").
- Put the small rectangular slabs back on a layer of mortar.
- Unblock the defecation hole of the first pit.

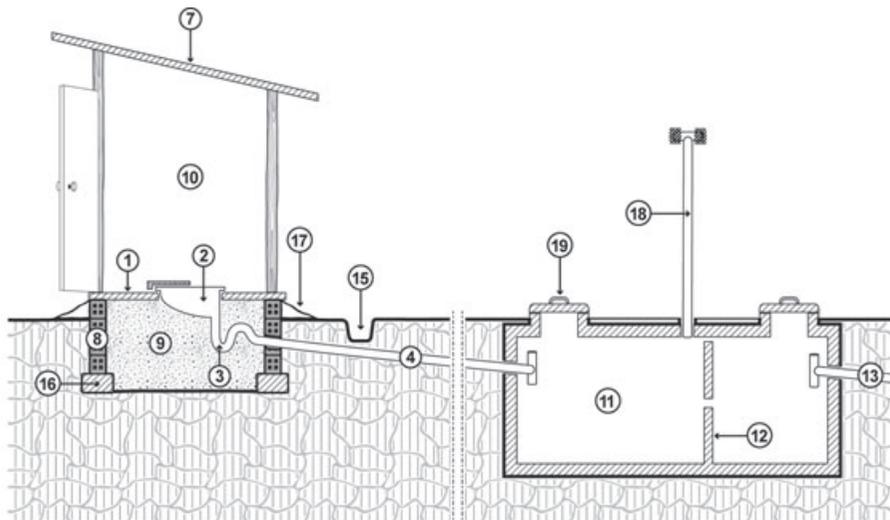
In this way, the alternation between pits may be repeated indefinitely until the latrine is completely worn out. The material taken out is inoffensive and is an excellent soil conditioner, with some fertilizing capacity.



Key	Input
1. Defecation hole in service	- String line, sticks and tape measure
2. Defecation hole on standby (blocked)	- Shovel, pick, miner's bar
3. Slab (potentially cast in situ)	- Sand, cement, gravel and clean water
4. Superstructure with door (semi-dark inside)	- Reinforcing bars
5. Removable small slabs	- Tools to prepare and cast concrete
6. Ventilation pipes	- Jute sacking or plastic sheeting
7 - 8. Separated twin pits	- Fired bricks or cement blocks
9. Screen (mosquito netting)	- Masons tools
(corrosion and UV-resistant material)	- Prefabricated standard and small slabs
10. Impermeable layer (mortar or clay)	- Material and tools to build the superstructure
11. Drainage channel	- PVC pipes (preferable diameter of 150 mm)
(at the sides and back of the latrine)	- Screen (e.g. mosquito netting)
12. Aquifer (water table)	- Experienced mason and 1 or 2 labourers
13. Reinforced concrete foundation (300 kg/m ³)	- Water supply with tap and evacuation system
14. Lean concrete layer (150 kg/m ³)	- Soap or ash, anal cleansing material (if required)
15. Open-jointed (honeycombed) lining	- Waste bin for sanitary towels (if required)
16. Sealed (closed) lining	- Temporary fencing material
17. Reinforced concrete upper ring beam (300 kg/m ³)	
18. Intermediate reinforced concrete ring beam (300 kg/m ³ ; optional, depending on the lining height)	
19. Air and light inlet covered with mosquito netting (only one, area = at least 3 times the vent section)	Measurements are indicated in m Drawings not up to scale

Remarks

- Before considering the construction of twin pit latrines, it is important to know if this technique is acceptable for the population as it implies handling of "faecal" material during pit emptying (even if the material doesn't resemble excreta anymore, nor is it harmful to health). Social, religious and/or cultural factors may forbid it and demand the use of another method for excreta disposal.
- The correct size of each pit is essential: each one should permit the storage of faecal and anal cleansing material for at least 2 years, during which all possible pathogens are certainly eliminated (biodegradation).
- When access for physically impaired persons is required, the dimensions of the superstructure will most probably have to be increased, implying that the pit will have to be bigger as well.
- The defecation hole that isn't in use should be covered with a lid that can't be removed easily (e.g. mortared). However, do not put a lid on the defecation hole of the pit in use as this prevents the air circulation and thus the VIP principle to work.
- Installing only one door per twin pit superstructure reduces the risk that both defecation holes would be opened and used at the same time, which would render their safe emptying process impossible.
- The use and regular maintenance of a twin pit latrine are very similar to a normal VIP latrine (T.B. 3.07), thus the related issues (e.g. gender separation, principle not suited for small children) and the facilities (e.g. handle bars and movable seat for physically impaired people, hand washing facilities, light outside latrine) are comparable as well.
- It is possible to transform a twin pit latrine into a real ecological sanitation (Eco-San) latrine by separating the urine from the faecal matter and stirring its content regularly (section 3.5 Further reading).
- Adding regularly wood ash, some green organic waste and vegetables can help already to reduce bad odours and potentially enhance the elimination of pathogens.
- After a minimum of two years for normal twin pit latrines (potentially less for Eco-San latrines), the "compost" may be taken out and be used as soil conditioner.
- The emptying process is a good moment to do a complete check-up of the twin pit latrine. Any damages should be repaired, in order to guarantee / increase the lifespan of the twin pit latrine.
- Remember to provide protective clothing and washing facilities (at least water and soap) to the workers emptying the pits.

B**Key****Input**

- A. Pour-flush latrine onset directly over a lined pit
 B. Pour-flush latrine connected to a septic tank

- | | |
|--|--|
| 1. Slab with footrests | - Excavation tools |
| 2. Water pan | - Building material and tools (for pit or septic tank) |
| 3. Water-seal (siphon) | - Slab with pan and water trap |
| 4. Drain pipe | - (PVC) drainage pipe (min. 75mm, max. 120mm) |
| 5. Simple pit or alternating offset twin pit | - Materials and tools for superstructure |
| 6. Intermediate reinforced concrete ring beam
(300 kg/m ³ ; optional, depending
on the lining's height) | - Water supply with tap and evacuation system |
| 7. Roof | - Soap or ash |
| 8. Masonry wall | - Soft anal cleansing material (if required) |
| 9. Backfill (e.g. sand) | - Waste bin for plastic bottles / sanitary towels |
| 10. Superstructure | |
| 11. Septic tank | |
| 12. Separation wall | |
| 13. Outlet pipe towards an infiltration system / sewer | |
| 14. Aquifer (water table) | |
| 15. Drainage channel (at the sides and back of the latrine) | |
| 16. Reinforced concrete foundation (300 kg/m ³) | |
| 17. Impermeable layer | |
| 18. Ventilation pipe with screen | |
| 19. Access holes with cover | |
| 20. Lean concrete layer (150 kg/m ³ ; stabilisation) | |
| 21. Open-jointed (honeycombed) lining | |
| 22. Sealed (closed) lining | |
| 23. Reinforced concrete ring beam (300 kg/m ³) | |

Measurements are indicated in m
 Drawings not up to scale

Offset lined pit

- The water-seal is connected via a pipe to a (double) offset pit, thus the water pan can be located within a building or an independent superstructure. The offset location also makes it easier to empty the pits when nearly full. Two offset pits with open-jointed lining put in parallel, each with an accumulation capacity for at least 2 years, permit a safe long-term alternating use of the system.
- Be aware that a minimum distance of 6 m between the pits and the dwellings / building foundations must be respected. The pits must be at least 30 m away (more for fissured underground and limestone) and downhill from all water sources, storage and treatment facilities.
- For soils with a good infiltration rate (T.B. 4.05), round pits that are lined with perforated concrete rings (T.B. 2.06) can be constructed. When alternating pits are installed, they should be at least 1.5 m from each other.
- For soils with a low infiltration rate (T.B. 4.05), large pits will be needed. Hence, the lined pits can be constructed following the steps as described for VIP latrines (T.B. 3.07), with adapted dimensions. The sealed partition walls aren't required, but the lean concrete stabilisation layer at the bottom is strongly recommended however. The VIP slabs need to be replaced by plain concrete slabs. It is advisable to install small slabs with handles (e.g. 0.3 m wide) side-by-side to be able to remove them more easily when the pit needs to be emptied (weight reasons). To avoid bad odours and to deny access to vectors and other animals, the slabs should be mortared to the pit lining.
- A shallow pit, with a foundation at the bottom and closed walls on top that are backfilled, form the support for the slab that integrates the water pan with water-seal.

Septic tank

- The water-seal is connected via a pipe to the septic tank (figure B), thus the water pan can be located within a building or an independent superstructure. The septic tank is attached to an infiltration system (T.B. 4.06; 4.07) or a closed sewer, if existent. When pour-flush latrines are used, the septic tank is certainly the preferred option for health structures, but they have to be designed and constructed by skilled people.
- The location, design and construction of a septic tank are described in T.B. 3.11. A minimum distance of 6 m between the septic tank and the dwellings / building foundations should preferably be respected.
- A shallow pit, with a foundation at the bottom and closed walls on top that are backfilled form the support for the slab that integrates the water pan with water-seal.

Operation and Maintenance

- Make sure that the users flush the latrine after each use. In order to obtain this:
 - Install a water point with a regular supply nearby the latrines.
 - Provide water containers with a suited volume to perform the flushing. Be aware that the amount of water needed per flush depends on the diameter of the water-seal: as a rule-of-thumb; a 90 mm diameter requires 2 – 3 l to flush effectively, whereas 4 – 5 l will be needed for a 120 mm diameter.
- Verify if the users have a water container for anal cleansing. If not, the size of the flushing container can be adapted or specific anal cleansing containers can be made available. Alternatives are to provide soft anal cleansing material that can be flushed (e.g. toilet paper), or that every cubicle is foreseen with a waste bin in which solid anal cleansing material can be deposited. These bins could potentially also be used to discard single use anal cleansing containers (e.g. plastic bottles) and sanitary towels.
- Try to have the slabs with water pan and the surroundings cleaned on a daily basis. Never pour disinfectants (e.g. chlorine products) or any other chemicals in the pour-flush latrines as they might inhibit the natural decomposition of the faecal material. It is only permitted during an epidemic of highly infectious diseases (e.g. cholera, Viral Haemorrhagic Fevers) to pour disinfectants or human wastes mixed with a (strong) chlorine solution into a pour-flush latrine.
- Check the pour-flush latrines frequently; if these toilets block they should be cleared quickly. Otherwise the material blocking the latrine will solidify and plug the water-seal. Never allow the pit to fill above the water-seal (siphon) level as it will clog up the whole system.
- Follow closely if the wastewater facilities function properly and do the necessary maintenance on the grease trap (T.B. 4.04).

Remarks

- As a general rule, the pour-flush latrine is mainly suitable for regions where water is abundant and habitually used for anal cleansing. In other cases, it is better to use dry pit latrines (T.B. 3.04), preferably VIP types (T.B. 3.07) for public buildings or even twin pit latrines (T.B. 3.09) if the removal of the residues is socio-culturally acceptable.
- Pour-flush latrines should be avoided in impermeable soils (e.g. clay) due to the very low infiltration rate.
- Allow for a spare 0.5 m of depth in the calculation of the pit size to cover the excreta in a safe manner when the pour-flush latrine (battery) is closed down, without causing fly and odour problems. The free space is not part of the effective pit volume.
- In places where (pour-)flush systems are commonly used, prefabricated pans (porcelain, plastic, smoothed cement) can often be found, but they are also available as emergency equipment. Verify that the water-seal has a minimum diameter of 75 mm, otherwise the risk of blockages is very high.
- The slope of the pipe behind the water-seal should be at least 2.5%, but 5% would be better. In case the distance in between the water-seal and the pit / septic tank is more than 2 m, a manhole should be foreseen in the middle to allow the pipe to be unclogged.
- Separate pour-flush latrines might be needed for gender purposes. The health structure's staff should always have their own latrines, separated from the patients' and visitors' facilities. Also small children might need their own adapted latrines.
- If there are physically impaired persons amongst the population, the size of the superstructure of some pour-flush latrines might have to be adapted. Make also sure to equip these adapted latrines with specific features, such as handrails and a (removable) seat, because some of these physically impaired people will be incapable to squat (section 3.5 Further reading). Don't forget to clean and disinfect these specific features regularly.
- An additional non-transparent screen or wall in front of the entry side of the latrine (battery) improves the privacy, which might lead to a more frequent use of the facility.
- It is essential to have a water point nearby so that the users can take water to flush the latrine after each use. If the water supply would (partly) fail, closure of these latrines and (temporary) replacement by a system not using water should be considered.
- These water points could also be used for hand washing, thus soap or ash should be available. Pour-flush latrines for handicapped people (wheelchair) should be provided with washing facilities within the superstructure. Make sure that the wastewater facilities are maintained correctly.
- It might be needed to install a refuse collection system nearby the pour-flush latrines to avoid users discarding their solid anal cleansing material, their anal cleansing container (e.g. old mineral water bottle) or their used sanitary towels in the water pan itself, thus blocking the whole system.
- In some contexts, it might be interesting to integrate the pour-flush latrines into sanitary blocks, together with personal hygiene facilities like (bucket) showers (T.B. 4.01). In case the women utilise reusable sanitary towels, special washing basins with drying lines could be provided in the female blocks.
- Light in and around the pour-flush latrines is highly recommended for safety / security reasons.
- Insecticide Residual Spraying (T.B. 7.15) of the interior superstructure walls (plastic sheeting included) has potentially an important impact on the fly population.
- When the pit is nearly full (0.5 m underneath the slab), close it down by filling the pit with soil. Since pour-flush latrines demand a considerable investment, it should be checked first if they can be emptied in a correct way (T.B. 3.13). With the lining, the pit is less at risk of collapse, so plenty of water can be added to render the sludge more liquid. However, do not empty the pit manually for at least two years. If the pour-flush latrines are demolished, water absorbing trees (e.g. mangos) can be planted in their pit to re-stabilize the underground. A septic tank can be emptied over and over again, but it has to be done in a safe manner (T.B. 3.13).
- When pour-flush latrines are required in acute emergencies, individual circular-shaped pits are recommended. Their lining can be made with perforated concrete rings (T.B. 2.06) or drums. A prefabricated (plastic) slab with water-seal (module) will have to be put on top of each lining and be anchored with pegs in the soil.

T.B. 3.11 Septic tank

A septic tank receives and pre-treats wastewater before disposal in an underground dispersal system (preferably infiltration trenches) or a closed sewer. The septic tank can receive all domestic wastewater (sewage and sullage). However, for big infrastructures like health structures and schools, it is mainly meant for black wastewater (sewage), because the required volume of the septic tank could become too big for the pre-treatment of all the grey wastewater (sullage) that is generated.

Functioning principles

- A septic tank is a container, often rectangular in shape, built just underground, in which wastewater is retained for 1 to preferably 3 days. During this period, the solid material settles. Over time, the faecal material will be decomposed by an anaerobic bacteriological process, which reduces the volume of the sludge. Although this biodegradation is reasonably active (depending on the temperature), the sludge does accumulate, which means that the tank needs emptying at regular intervals, generally every 1 to 5 years.
- The effluent from the tank is still contaminated by pathogens, thus it cannot be released directly in the open environment. Therefore, dispersal in the underground, preferably via infiltration trenches (T.B. 4.07) is essential to benefit from the natural filtration process. In places where infiltration trenches wouldn't work because of the limited soil permeability, a filtration system will have to be installed before the effluent can be disposed of into a river or a stream. A perfect alternative might be a correct and closed sewerage system, if it would be already available at the site.

Design

Although a septic tank is constructed in a similar way as a grease trap (T.B. 4.04), it has its own important design features, as following:

- In order to reduce the concentration of suspended material in the effluent, the tank is divided into two interconnected compartments, the first having double the volume of the second. The effective depth of the liquid zone is 1.2 to 1.7 m. The total length of the tank is usually 2 to 3 times its width.
- The volume of the septic tank is calculated on the basis of a 3 days retention time of the quantity of water entering each day.
- The septic tank has an access hole with cover for each compartment, to ease the sludge removal.
- The septic tank needs a ventilation pipe for the gasses that are created during the decomposition.

Operation and Maintenance

- The septic tank should be emptied frequently; a simplified estimation is when it is 1/3 full of sludge. The frequency is thus given by:

$$n = 1/3 \times (\text{Veff}/(\text{S} \times \text{N}))$$

With n = number of years before de-sludging
 Veff = effective volume of the septic tank; volume of the tank that can be filled in m^3
 S = sludge accumulation rate in $\text{m}^3/\text{person year}$
 N = number of users

- The sludge accumulation depends on the temperature, but a figure of 0.025 – 0.03 m^3 per person a year can be considered sufficient as estimation, if only sewage passes through the septic tank. After emptying the septic tank, it is necessary to refill it with water. Some of the old sludge can also be poured into the tank, to accelerate the growth of decomposing bacteria.

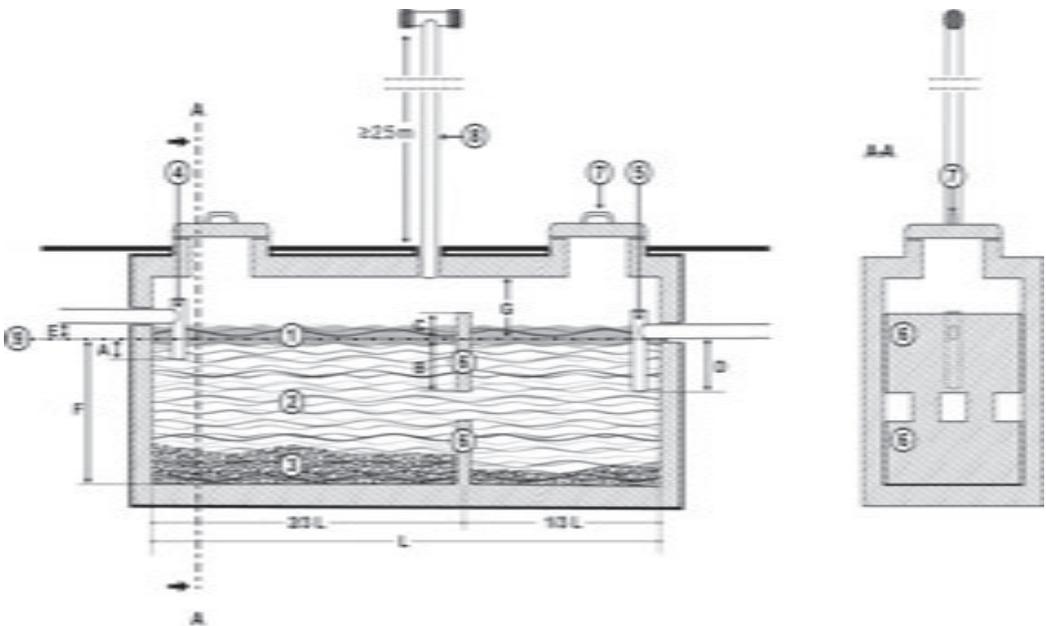
Example

A health structure with 4 pour-flush latrines; according to the Essential Requirements (T.B. 1.08): 20 users each.

Effective volume of septic tank: 12 m^3 (5 m length, 2 m width and 1.2 m effective depth).

$$n = 1/3 \times (12/(0.03 \times 80)) = 1.67 \text{ year}$$

Thus every 1.67 year (20 months), the septic tank should be emptied.



Key

Input

1. Floating material (oil, fat, grease)
2. Clarified liquid
3. Settled solids
4. Inlet tee
5. Outlet tee
6. Partition wall to retain solids and floating material
7. Access holes with covers
8. Ventilation pipe with screen
9. Reference level indicating effective depth

- Temporary fencing material
- Plans
- Shovels, picks, hoes, miner's bars
- Builders tools
- Sand for sub-base
- Shuttering timber
- Concrete (quantity calculated according to tank size), concrete blocks, prefabricated elements or complete component
- Pipes and inlet and outlet tees (minimum diameter 100 mm)
- Ventilation pipe with Tee and mosquito netting

- A. 20% of effective depth
 B. 40% of effective depth
 C. 20% of effective depth
 D. 40% of effective depth
 E. At least 75 mm
 F. Effective depth of water (min 1.2 m, max 1.7 m)
 G. At least 0.3 m
 L. Total inner length of septic tank

Drawing not up to scale

Remarks

- It is not recommended for health structures to combine the degreasing of sullage (grey water) with the pre-treatment of sewage (black water) by passing both through the same septic tank. To cope with the considerable volumes of sullage generated in health structures, the required capacity of their septic tanks might be very important in order to respect the minimum retention time for the sewage (1 to preferably 3 days). Grease traps (T.B. 4.04) are definitely a better option for grey water as their minimum effective volume should only be double the maximum hourly flow entering the trap.
- The location of the septic tank is dictated by the position of the dispersal area (e.g. infiltration trenches, T.B. 4.07), but it should also be nearby the buildings that it is serving. The tank should be away from vehicular passage, but accessible for maintenance however.
- Make sure there is enough land available for the underground dispersal system and that the soil allows a sufficient infiltration rate (T.B. 4.05).
- If the water table is not deep enough (should be at least 2 m deep) or the soil isn't very absorbing, do contact your technical referent for further advice.
- A temporary fence should be installed before the works begin.
- A septic tank may be built in situ in concrete or masonry-work (e.g. cement blocks) and made watertight with plastering mortar (T.B. 2.05), or alternatively with prefabricated panels or a complete tank of concrete, fibreglass or plastic. If built in situ, the construction steps as described for the grease trap (T.B. 4.04) can be followed, taking in consideration the specific dimensions and ratios of a septic tank.
- Whatever the construction method, the tank must be watertight and strong enough to resist to soil and possible groundwater pressures. It should rest on a sub-base of sand several centimetres thick.
- The covers of the septic tank should be at least 0.1 m above ground level to avoid infiltration of surface water (e.g. rainwater).
- The minimum diameter of the inlet and outlet pipes with their respective T-piece should be at least 100 mm, and their slope at least 2.5%, although 5% is preferable.
- The covers of the septic tank should be at least 0.1 m above ground level to avoid infiltration of surface water (e.g. rainwater).
- The gasses resulting from anaerobic decomposition in the septic tank should be evacuated by a ventilation pipe with a minimum diameter of 100 mm (preferably 150 mm, if available). The pipe should be installed at such a place and such a height that there is no odour nuisance (take into account the dominant wind direction). It is preferably located directly on top of the septic tank, if possible. The outlet of the ventilation pipe must have a stainless steel, aluminium, PVC coated fibreglass or even a nylon screen to avoid vectors entering. Regular checks of this screen are strongly recommended, and it should be replaced when it is not longer intact.
- Chlorine products and detergents used for a health structure's normal maintenance and cleaning will not affect the tank's functioning (bacterial activity). However, high dosages of disinfectants or any other chemicals should not be evacuated via the septic tank as they might inhibit the natural decomposition of the faecal material.
- It is not necessary to use special additives in the septic tank to be re-activated after it has been emptied. Some of the old sludge could be added to accelerate the growth of decomposing bacteria, but generally the new faecal material collected in the septic tank is rich enough in micro-organisms to start the biodegradation.
- Septic tanks should be inspected regularly; once every 6 months for public buildings and health structures.

T.B. 3.12 Raised pit latrines in problem soils

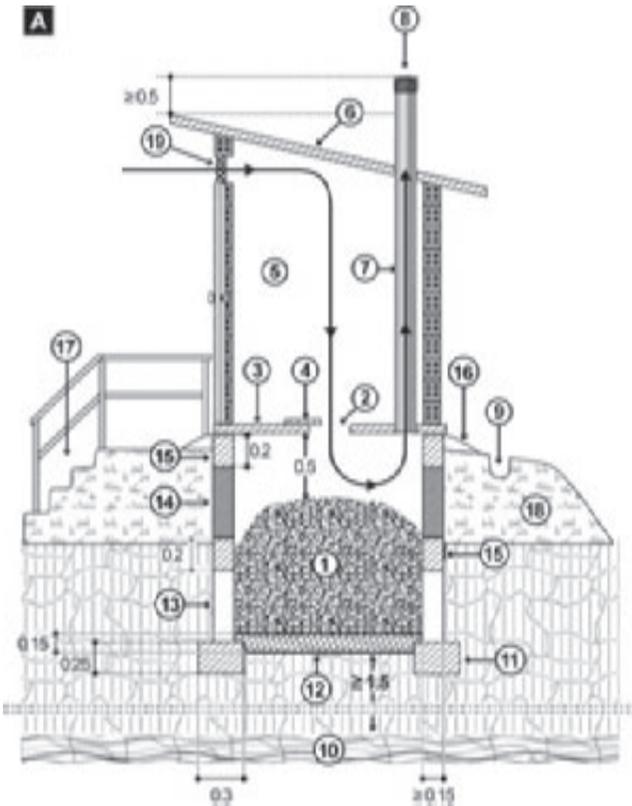
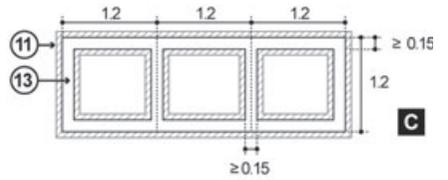
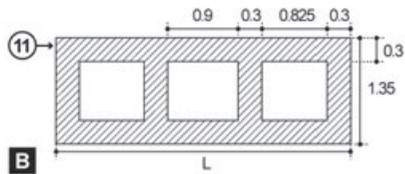
In some areas, it is difficult to build latrines because of unfavourable (soil) conditions like a rocky bottom, risk of flooding, or a high water table. An option to provide adequate sanitary facilities in these situations is to raise the latrine pit partly aboveground. Whereas the aboveground part of the pit should be completely watertight, the underground part (at least 0.5 m deep) must be permeable enough to allow the infiltration of liquids. Simple pit, VIP and twin pit latrines can all be raised.

Construction

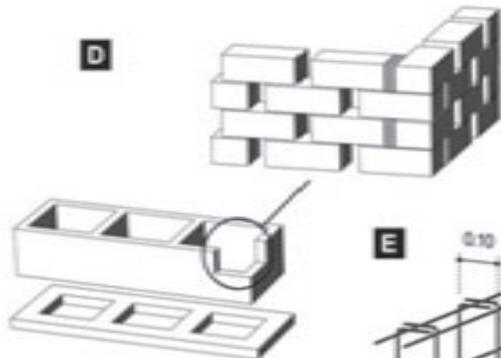
- Determine the effective pit volume, which is depending on the number of potential users, the accumulation rate and the desired lifetime of the latrine (section 3.4.6).
- Choose a site at least 30 m away (more for fissured underground and limestone) and downhill from all water sources, storage and treatment facilities. The latrine (battery) must have easy access, not less than 5 m and not more than 50 m away from the dwellings (< 30m from buildings within a health structure).
- Prepare the site for construction: remove all debris, flatten the surface, put up a temporary fence, implement soil texture and permeability tests (T.B. 4.05), and determine the depth of the water table. The depth of the water table can be estimated by verifying the water level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe in the ground, at least 2 m beneath the ground surface. When pulled out, the rod or (the earth inside) the pipe should be dry. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level.
- Decide on the maximum depth of the underground part, with respect for the minimum required vertical distance of 1.5 m between the bottom of the pit and the highest possible water table. As such, in order to leave an additional 0.5 m depth available for the infiltration of liquids, the highest possible water table should be at least 2 m deep for homogeneous soils. The required vertical distance for heterogeneous soils is difficult to predict however.
- Calculate the remaining height needed for the aboveground part (receiving slabs with standard dimensions) to obtain the desired total volume, including the 0.5 m required for the free space. In case the height of the aboveground part would surpass 2 m, non-standardised concrete slabs with a bigger size can be used, but be aware of the weight increase this will imply.
- Bring in the needed material and equipment, based on the calculations and decisions made.
- Lay out, using string lines, the excavation area according to the outer dimensions of the foundation (as per figure B, or a bigger surface if non-standardised slabs or a raised twin pit latrine are desired).
- Excavate the pit as deep as possible, keeping its vertical walls straight.
- Dig within the excavated pit a trench system of 0.25 m deep (as per figure B).
- Prepare and install some reinforcing bars inside the trench. Make sure that the reinforcing bars stay at least 30 mm away from the sides and bottom of the trench (use spacers).
- Pour concrete (300 kg/m³; T.B. 2.05) inside the trench system to form the pit's foundation. Vibrate the concrete to remove all the air. Keep the concrete moist for a week with plastic sheeting or jute sacking that needs to be wetted twice a day.
- Dig another 0.05 m of soil within the foundation compartments, after the concrete has settled.
- Build on top of the foundation, which has hardened for at least 3 days, the open-jointed (honeycombed) lining and the sealed (closed) partition walls that divide the pit into different compartments (as per figure C). The lining and partition walls, erected in cement blocks or a double layer of fired bricks until approximately 0.1 m underneath the ground surface, should overlap correctly in all the corners (as per figure D) to be able to resist the ground pressure.
- Arrange on top of the lining and the partition walls the casing for the intermediate concrete ring beam.
- Prepare and install every 0.2 m the required reinforcing bars inside the casing (as per figure E).
- Pour the concrete (300 kg/m³) inside the casing, while tapping gently on its sides. The concrete can also be vibrated by poking it with a reinforcing bar. Keep the concrete moist for a week to ensure correct curing.
- Pour a layer of lean concrete (150 kg/m³; T.B. 2.05) at the bottom of the pit. It will give extra support to the lining. Keep this concrete moist for a week and cover the whole pit with plastic sheeting.
- Backfill the space in between the pit lining and the excavated hole with gravel (honeycombed part) and compacted soil (intermediate concrete ring beam).
- Build on top of the intermediate ring beam that has hardened for at least 3 days the sealed lining and partition walls to a height of maximum 2 m. The lining and partition walls, built with cement blocks or a double layer of fired bricks, should overlap correctly in all the corners.

- Arrange on top of the lining and the partition walls the casing for the upper concrete ring beam.
- Prepare and install every 0.2 m the required reinforcing bars inside the casing (as per figure E).
- Pour the concrete (300 kg/m³) inside the casing, while tapping gently on its sides. The concrete can also be vibrated by poking it with a reinforcing bar. Keep the concrete moist for a week to ensure correct curing.
- Build a compacted earth mound around the whole construction. This can be done in several soil layers, each one watered and rolled to be compacted. The mound slope depends on the stability of the soil used. At the top of the earth mound, it is advisable to foresee a little platform around the structure for safety reasons. Plant in a later stage some grass on the mound to reduce its erosion.
- Add an impermeable layer (mortar or clay) against the aboveground part of the upper ring beam.
- Install prefabricated slabs (T.B. 3.08) on the upper ring beam after it has hardened for at least 3 days. To ensure a secure seating, every slab should have a good overlap over its entire circumference with the lining and partition walls (respectively 0.15 and 0.075 m) and be fixed with a 10 mm thick mortar layer (T.B. 2.05).
- Construct the superstructure with its potential accessories, keeping local preferences in mind. As a raised latrine is an important investment, it's recommended to make the superstructure also in durable materials. The superstructure should have a door.
- Fit a roof to the superstructure with its slope carrying rainwater towards the back of the latrine (battery).
- Make a drainage channel at the back and the sides of the latrine (battery) to lead the runoff water down and away, thus protecting the whole construction against erosion.
- Build an access ramp (for impaired persons) and/or a stairway in concrete or masonry-work on the earth mound to allow easy access to the latrine (battery). A handrail is strongly recommended because the access can get slippery when wet.

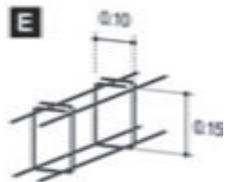
Key	Input
A. Vertical cut of the raised VIP latrine	
B. Dimensions of the foundation	
C. Dimensions of the compartments (lining and partition walls)	
D. Detail of the masonry overlap in a corner of the lining	
E. Detail of the ring beam reinforcement	
1. Effective pit volume (filled)	- String line, sticks and tape measure
2. Defecation or squatting hole without cover	- Shovels, picks, miner's bars
3. Slab	- Sand, cement, gravel and clean water
4. Footrests	- Reinforcing bars
5. Superstructure (semi-dark inside)	- Jute sacking or plastic sheeting
6. Roof	- Building tools for concrete, masonry-work
7. Ventilation pipe	- Fired bricks or cement blocks
(internal size depending on the material used)	- Prefabricated slabs
8. Fly screen	- Material and tools for the superstructure
(corrosion and UV-resistant material)	- PVC pipe (diameter of 150 mm), screen
9. Drainage channel at the sides and back of latrine	- Additional soil for the earth mound
10. Aquifer (water table)	- Roller to compact the earth mound
11. Reinforced concrete foundation (300 kg/m ³)	- Material and tools for the stairway / ramp
12. Lean concrete layer (150 kg/m ³)	- Water supply with tap and evacuation
13. Open-joint lining (cement blocks / fired bricks)	- Soap or ash, anal cleansing material
14. Sealed lining (cement blocks / fired bricks)	- Waste bin for sanitary towels
15. Reinforced concrete ring beams	
16. Impermeable layer	L = (n x b) + 0.15m
17. Stairway or access ramp (for wheelchair users) with railing	With L: total length of the foundation
18. Earth mound	n: number of slabs (max. 6)
19. Air and light inlet covered with mosquito netting (only one, area = at least 3 times vent section)	b: width of a slab
Dimensions are indicated in m	Drawings not up to scale



D



E



Remarks

- When choosing the site, ensure that buildings (e.g. health structures) and living areas are not downwind of the raised pit latrines. If the VIP model is chosen, it should be built on an open space, away from trees, buildings or other objects that could impede air movement.
- The construction method described is for raised pit latrine batteries of up to 6 standard slabs. As a raised pit latrine is a considerable investment, there is a tendency to make it more as a VIP model (as per figure A) or even as a twin pit model. The special features for these models are described in T.B. 3.07 and 3.09.
- Single (simple) raised pit latrines can be built as well with this method. An alternative is the individual circular-shaped raised pit latrine. This can be made by installing perforated concrete rings underground, and plain concrete rings (T.B. 2.06) aboveground within a compacted earth mound. The rings should be cemented and preferably bolted together to be watertight.
- Be aware that the infiltration rate of a raised pit latrine can be low, certainly when the permeable part of the lining is limited in size. This could mean that the pit will have to be emptied on a regular basis (T.B. 3.13), certainly when water is used for anal cleansing. As such, raised pit latrines should preferably not be made with a pour-flush system as lots of water will be introduced (T.B. 3.10).
- In case the water table level is less than 2 m deep, the normal construction of raised latrines with earth mound won't be sufficient to avoid microbiological contamination of the groundwater. Following options are possible under these circumstances:
 - Make a pit with its bottom close to or even within the aquifer, which will result in contaminated groundwater. But it is usually easier and cheaper to develop onsite sanitation and find an alternative solution for the water supply (e.g. during emergencies, it is easier to supply potable water than to evacuate excreta on a daily basis). However, an in-depth assessment is required before the construction of the latrines begins, to make sure that the groundwater is not exploited for human consumption at present, nor will be in the near future.
 - Install an impermeable reservoir, partly underground in a pit (even within the aquifer) and partly aboveground in an earth mound, and closed on top with latrine slabs. This impermeable reservoir can for instance be a large (round) plastic or fibreglass water storage tank, weighted down so it doesn't float if it would be located inside the aquifer. This avoids groundwater contamination, but the tank will often have to be emptied in a safe manner (T.B. 3.13). The solution of an impermeable reservoir can also be interesting for excreta disposal facilities that have to be constructed on rocky grounds.
- In case of very permeable or fissured soil, the risk of microbiological contamination of the groundwater can potentially be reduced by making the excavation a lot bigger (e.g. 1 m on all sides,) and by backfilling the gap between the hole walls and the permeable lining with fine sand, topped up with compacted soil at the level of the sealed lining. The sand layer will filter the pathogens out to a certain extent, which will reduce, but not completely avoid the contamination of the groundwater.
- In case the underground soil is too unstable, the pit will need to be supported with struts or be made conical.
- Allow for a spare 0.5 m of depth in the calculation of the pit size to avoid unpleasant sights and excreta splashing out during use. It also permits to cover the excreta in a safe manner when the latrine is closed down, without causing fly and odour problems. The spare space is not part of the effective pit volume.
- Separate raised pit latrines might be needed for gender purposes. The health structure's staff should always have their own latrines, separated from the patients' and visitors' latrines. Special facilities or potties might be needed for children as well.
- If there are physically impaired persons, the size of the superstructure might have to be adapted. Make also sure to equip the adapted latrines with specific features, such as handrails and a seat, because some of these people will be incapable to squat (section 3.5 Further reading). Additional attention will have to go to the earth mound, like a more gentle slope. An access ramp will be essential for people in a wheelchair.
- Make sure that correct hand washing facilities with water and soap (or ash) are provided in the direct neighbourhood of the raised pit latrines. Make sure that the wastewater facilities are maintained correctly.
- A waste bin close to the trench latrines is recommended for the disposal of sanitary towels.
- Outside lights around the raised pit latrines are highly recommended for safety / security reasons.
- Insecticide Residual Spraying (T.B. 7.15) of the raised pit latrines' interior superstructure walls has potentially a high impact on the fly population.
- The operation and maintenance activities are similar to the type of latrine chosen, e.g. simple pit, VIP or twin pit latrines (T.B. 3.04; 3.07; 3.09).

T.B. 3.13 Emptying latrines and/or septic tanks

Emergency latrines are mostly demolished when they are full. However, excreta disposal facilities, where the investment was significant merit to be emptied for reuse. Their design (e.g. twin pit latrine, septic tank) is sometimes even developed to be emptied. Nevertheless, it should be verified (normally already during the designing phase) if social, religious and/or cultural factors do not forbid this action.

Implementation

Manually

Due to the contamination risks, latrines should not be emptied manually, except if they have been closed down for at least two years. The design of the latrine should permit manual emptying (e.g. twin pit latrine). However, in many countries, this practice is socio-culturally not acceptable for the population.

Vacuum suction tank

This system, which is often used for sludge trucks, is very effective because it “sucks” up the sludge by means of under-pressure that is created in a sewage tank. As the moving parts of the “vacuum” pump don’t get in contact with the sludge, the breakdown frequency of such a pump should normally be low. Another advantage is that this system can be used (at least theoretically) for all kinds of excreta disposal systems (latrines and septic tanks), as long as the sludge is still liquid enough (this is not the case for twin pit and Eco-San latrines that transform faeces into solid compost). The liquid sludge of septic tanks and latrines is emptied quite quickly. However, this fast “suction” can lead to the collapse of partially lined or unlined pit latrines. The other inconvenience is that these systems are very expensive.

Trash pump

Although resembling motor pumps used for water, trash pumps have some specific features. Their inlet isn’t located at the centre of the impellor, but above. Their impellor has only a few solid blades, potentially with cutting edges. Another difference with a motor pump is that their pump house can easily and rapidly be opened for de-blocking and cleaning purposes. Hence, these centrifugal trash pumps are specially designed to drain liquid sludge that contains quite some solid particles (e.g. with diameters up to 30 mm). They can be used to empty septic tanks or latrine pits containing a lot of liquids. The use of a strainer with rather big holes is obligatory.

Diaphragm (membrane) sludge pump

These volumetric pumps are specially designed to drain sludge still containing relatively big solid particles (e.g. with diameters up to 60 mm). So they are suited to empty septic tanks and latrines if their sludge is liquid enough. The maximum delivery head and flow (T.B. 2.26) of a diaphragm pump are only half or even less of those of a trash pump with a similar engine, but it can deal with double sized particles. These membrane pumps are often driven by combustion engines. The use of a strainer with rather big holes is advised.

Submersible grinder pumps

These centrifugal pumps have to be lowered in the sludge. Depending on their hardness, potential “solid” particles present in the liquid sludge (up to a certain size) will be grinded into small pieces by the cutting blades of the impellor. These pumps aren’t really suited for latrines having their slab fixed on the pit because their diameter is often too big to be lowered via the defecation hole. These pumps are more appropriate to empty septic tanks. As an electrical motor drives this kind of pumps, an adapted generator will often be needed for field use. Verify if the chosen generator is adapted to the starting current of the pump motor.

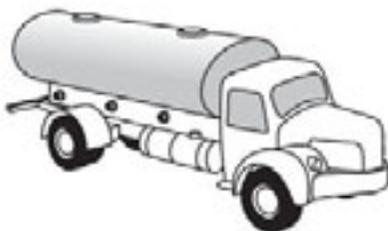
Motor pump

In the early stages of an emergency when no other alternatives are available yet, a standard 3" motor pump can be used to empty the emergency latrines, at least when they contain a lot of liquids. This can be the case for latrines built in an underground that doesn't have a high infiltration rate (e.g. clayey soil; T.B. 4.05) and where the users do anal cleansing with water. The sludge can also be liquefied more by adding water before the pumping starts, but this increases the risk of the latrine pit collapsing. A motor pump used for emptying sludge should never be used anymore for other purposes, and certainly not for potable water!

Transport tanks

Sludge trucks / "vacuum suction" systems have their transport tank integrated. For the other pump systems, (round) metallic or solid plastic tanks can be used. They need to be leak proof and have big drains to ease the removal of the sludge. The tanks have to be correctly fixed to their transport means (e.g. a truck) to avoid accidents. In the very first phase of an emergency, a 2 or 5 m³ (transport) bladder can be used if no other means are available at all. This bladder should never be used anymore for other purposes afterwards, certainly not for potable water!

A



B



C



D



Key

- A. "Vacuum suction" tank
- B. Trash pump / motor pump
- C. Diaphragm (membrane) sludge pump
- D. Submersible grinder pump

Remarks

- Never empty a latrine / septic tank manually with recipients such as a bucket. Pathogens present in the sludge are serious health hazards to the workers. The only exceptions are the twin pit latrines where the excreta has been transformed into harmless compost (at least if the decomposition time of minimum 2 years has been respected) or where ecological sanitation systems are used (Eco-San is only briefly mentioned in these guidelines).
- Always verify if a municipal or private sludge truck is available (for rent) in the region. Before signing a contract with the owners, check if the sludge truck functions properly, how much capacity it has, where they dump the excreta and if they have the permission to do so.
- All systems, except the submersible grinder pumps are “suction” systems, thus they are not able to remove sludge out of deep pits (and certainly not deeper than 7 m) and/or pits that are located far from the “suction” system because the liquids can be quite viscous.
- All the equipment and the surroundings that have been in contact with the sludge should be thoroughly rinsed with clean water immediately after the works.
- Equipment that has been into contact with sludge should never be used anymore for other purposes afterwards.
- Make sure that the sludge tanks don't leak because they will leave a contaminated trail over the whole transport route.
- The sludge should be buried at a safe place where it will not cause any public health or environmental risks, or it should be brought to a certified treatment plant (although that the latter is not often available in low-income countries). The burial trench should be at least 800 m away from dwellings, 50 m away from water points, and for homogeneous soils at least 1.5 m above the highest possible groundwater table (at the end of the rainy season). The required vertical distance for heterogeneous soils is difficult to predict however.
- Regular checks should be performed to verify if the sludge is correctly disposed of at the right spot.
- Make sure that the operators have good protective clothing and do wash thoroughly their hands with water and soap after finishing the job (e.g. before the lunch, at the end of the working day). Daily showers are also highly recommended. Do foresee the necessary facilities for these essential hygiene practices.

Disposal of Runoff Water and Wastewater

Narrative

Technical briefs

- T.B. 4.01 Showers
- T.B. 4.02 Washing facilities
- T.B. 4.03 Manhole / Collection - Distribution box
- T.B. 4.04 Grease trap
- T.B. 4.05 Soil stability and permeability tests
- T.B. 4.06 Soak away pit
- T.B. 4.07 Infiltration trench
- T.B. 4.08 Evapo-transpiration area

Chapter 4



4.1 Why do runoff water and wastewater have to be disposed of?

The health risks due to pollution carried by wastewater as well as the presence of stagnant water are the following:

- Spread and multiplication of pathogenic agents such as cholera vibrio, schistosomonas;
- Chemical contamination of water (e.g. nitrates, detergents) and ecological disturbance / pollution of aquatic environments (ground and surface water);
- Production of noxious and corrosive gases;
- Breeding of insect vectors (e.g. mosquitoes).

Other nuisances are runoff water and wastewater entering in and/or causing erosion to shelters and other buildings, roads, pit latrines, waste pits which can lead to difficult and unsafe access to these facilities and even bigger health risks (e.g. flooded latrines which spread the excreta all over).

4.2 What kinds of wastewaters do exist?

A clear distinction has to be made in between runoff water (e.g. rainwater that doesn't infiltrate naturally in the ground) and wastewater (used water). As long as the runoff water doesn't get in contact with waste (water), it isn't considered being contaminated, thus it doesn't need real "treatment". However, standing runoff water can be a breeding ground for vectors, and thus needs to be removed via a separated evacuation system.

Risks associated with wastewaters depend on their origin and thus their degree of pollution, and it is useful to classify them as following:

- "Domestic" wastewater
 - Sewage (black water): water carrying excreta in suspension, thus containing bacteria, viruses, faecal parasites and also nitrogen.
 - Sullage (grey water): water from water distribution points, kitchens, (hand) washing areas and from health centres, often containing detergents (with nitrogen and phosphorus components), grease and fats, as well as (faecal) micro-organisms, suspended and/or dissolved organic matter.
- Specific wastewater from humanitarian interventions
 - Sullage coming from laboratories: they may contain hazardous chemical substances, as well as micro-organisms (e.g. of faecal origin).
 - Liquid residues from water treatment systems: backwash water or sedimentation sludge will be highly concentrated with dirt and chemicals when coagulants are used.
- Agricultural wastewater
 - High concentration of nitrates and pesticides in water supply.
- Industrial wastewater
 - Wastewater from mining.
 - Contamination of surface water and groundwater by chemicals.

4.3 Where / When should runoff water and wastewater management be implemented and by Who?

All runoff water should always be controlled to avoid risks of flooding or stagnant water. In order not to contaminate the big amounts of runoff water that can't be infiltrated, a separated and appropriate evacuation system for the wastewater and the rainwater has to be foreseen.

For every situation where water is supplied, there will be wastewater generated. Therefore, there should always be a removal and "treatment" system, which prevents stagnant water and local contamination of potable water resources.

Wastewater within a humanitarian context can be found at a lot of different places; for instance:

- Water points: e.g. spillage around wells and taps, leading to standing water
- User points: e.g. kitchen, laboratory, showers (T.B. 4.01), washing areas (dishes, bathing, laundry; T.B. 4.02), hand washing stations.
- (Pour-) flushing toilets.
- Water treatment sites: e.g. sludge from assisted sedimentation or from backwashing of filters.

Appropriate facilities should always be foreseen close to the site where the wastewater is generated. Wastewater from laboratories (mixed with chemicals) and health structures do often demand some extra attention however. In these cases, additional support must be required from your technical referent.

The construction, operation and maintenance should be discussed and agreed upon with all the stakeholders (e.g. aid-agency, population, local authorities) in order to have the facilities build, used and maintained correctly (e.g. no washing at water points lacking a grease trap, no dumping of solid waste in the open drainage canals). Health promotion activities can help to achieve this.

4.4 How should runoff water and wastewater be managed?

4.4.1 Planning and organisation

For correct planning and organisation of runoff water and wastewater disposal, it is necessary to follow all the different steps described in chapter 1. Within a humanitarian context, a lot of the facilities that generate and dispose of wastewater will have to be provided according to the essential water and sanitation requirements for health structures or camps (T.B. 1.08; 1.09), but adapted to the needs, habits and culture of the beneficiaries (e.g. traditionally, do the people stand or kneel during laundry activities). The more users' friendly and appropriate the facilities are, the more they will be used. Information and promotion activities will need to be organized for the population to use and maintain the facilities correctly.

4.4.2 Technical process

The technical process of runoff water and wastewater management consists of:

1. Removal of the water ("transport"),
2. Potential pre-treatment of the water,
3. Final disposal.

1. Removal

A removal system should be able to evacuate runoff water or wastewater, so as to avoid stagnant water, and to channel it to the treatment / disposal site without contaminating the local environment. The collection surface for runoff water or wastewater should be gently sloped (at least 1%) and preferably cemented. The removal system design may be based on different techniques:

■ Open channel

This is the most simple and least costly technique but it entails maintenance problems: e.g. blockages, stagnant water, damage to the sides of the channel, people dumping their garbage in it. This technique should only be used for drainage of runoff water or for evacuation of sillage over short distances. The channel should preferably be cement-lined and with enough slope to be self-cleansing (about 1.5%). In case cement-lining would be impossible, the open channel could be reinforced with boulders to avoid collapse but leaving enough gaps for the water to pass easily.

■ Gravel drain

For sillage, a wide piece of plastic sheeting can be laid in an open channel, filled up with coarse gravel and finally folded over the gravel to form a sort of pipe. The whole gravel drain should be covered with an earth layer. As this type of drain is impossible to unblock, the sillage should never contain suspended or greasy material. It should only be used in (the early stages of) an emergency, for example at a dispensary or a laboratory.

■ Pipe

This is the most effective way of removing runoff water and all kinds of wastewater, but also the most expensive one. Various types of pipe may be used (e.g. PVC, polyethylene, cement), with a minimum diameter of 100 mm. The slope (minimum 1% and minimum 1.5% for black water) and the pipe diameter should be adequate for the flow, and the pipes should be buried. Special care should be taken at crossing places of vehicles and big animals (e.g. plastic pipe covered by concrete slabs or installed within a bigger diameter steel pipe). Manholes and collection boxes (T.B. 4.03) should be included when long and/or complex drainpipe systems are installed. These can help during the regularly needed checkups in order to deal with blockages.

2. Potential pre-treatment

It may be necessary to pre-treat the water to remove solid or dissolved matter that could hamper the removal and/or the final disposal:

- Screen to remove floating and bulky objects.
- Sand trap to separate sand and soil, via sedimentation.
- Grease-trap (T.B. 4.04) to eliminate oily and greasy material (e.g. soap) in wastewater (sullage).
The sand and grease trap can be combined.
- Septic tank (T.B. 3.11) to eliminate faecal material in sewage.
- Sedimentation hole to eliminate flocks from water treatment.

If not well operated and/or maintained, all these structures can block the wastewater system and possibly become ideal vector breeding sites as well.

3. Final disposal

Where rainwater doesn't infiltrate naturally in the ground within few hours, the runoff water can be evacuated directly to surface water like rivers or streams, but downhill of existing water intake points. Swamps or lakes can also be considered as possible evacuation locations when no water is taken for consumption at these places. As runoff water shouldn't be contaminated, the evacuation can be done without specific treatment, except possibly the removal of floating and bulky objects.

For wastewater however, many different techniques exist and the choice of a system, or a combination of several, depends on the type and the quantity of wastewater to be treated.

In settings of low-income countries, the methods, as described in these guidelines, should be as simple, as affordable and as durable as possible, so that they can continue to be operational. Completely natural treatment methods are therefore preferable. Infiltration combines the final disposal with a form of natural treatment. It uses the natural capacity of the soil to fix particles present in the water by filtration, and to purify the water by a process of biological decomposition capable of retaining organic matter including micro-organisms, and some chemical pollution.

This natural capacity is always extremely variable, depending on the soil type (ground condition):

- A mature organic-rich soil is host to intense biological activity favouring purification, but it blocks rapidly and so has a reduced infiltration potential;
- Conversely, a sandy soil (generally considered as a good filter) with coarse structure may have an infiltration rate which is too rapid and which does not allow sufficient time for purification if the water table is too close to the surface;
- For the same reasons, a fissured rock would only have a small purifying capacity.

In practice, following parameters should be studied in order to design the wastewater facilities:

- The slope of the ground (topography; T.B. 2.24): a slope too steep may encourage water to remerge and thus to contaminate the ground surface.
- The infiltration rate: determined by percolation tests with potable water (T.B. 4.05).
- The groundwater level: a high level (e.g. during the rainy season) will increase the risk of groundwater pollution and won't permit the infiltration of large amounts of wastewater.

The principle of infiltration / dispersal is used (sometimes in combination with other principles) in the following final disposal techniques:

- Soak away (SA) pit (T.B. 4.06),
- Infiltration trench (IT) (T.B. 4.07),
- Evapo-transpiration (ET) area (T.B. 4.08),
- Irrigation furrow (IF) (only for spilled clean water at water points),
- Sewer (S).

Overview of the different steps for runoff water and different kinds of common wastewater:

	Removal	Pre-treatment	Final Disposal
Runoff water	Channel, Drain	Not needed	River, Stream
Water point spillage	Channel, Drain, Pipe	Not needed	IT, SA, IF, ET, S
Sullage (grey water)	Pipe	Grease trap	IT, SA, ET, S
Sewage (black water)	Pipe	Septic tank	IT, SA, ET, S

If all final disposal methods for wastewater fail where it rains a lot, there is still the possibility to mix the pre-treated wastewater (floating and bulky objects, grease, fat, oil and excreta removed) with the runoff water and to drain everything away towards surface water. This dilution will reduce the concentration of pathogens and thus the risk of contamination. But the drainage should be done in an as large and as fast flowing river as possible, and downstream of sites where surface water is collected (e.g. water supply intake). It should also be verified downstream if other people than the beneficiaries do use the surface water for their daily needs and if the discharge has a potential negative impact on their health (e.g. by bacteriological analyses).

4.5 Further reading

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Environmental Health Engineering in the Tropics
 Willey, 1993

J. Davis, R. Lambert

Engineering in Emergencies: a Practical Guide for Relief Workers
 Intermediate Technology, RedR, 2002

P. Harvey, S. Baghri, B. Reed

Emergency Sanitation
 Water, Engineering & Development Centre (WEDC), 2002.

T.B. 4.01 Showers

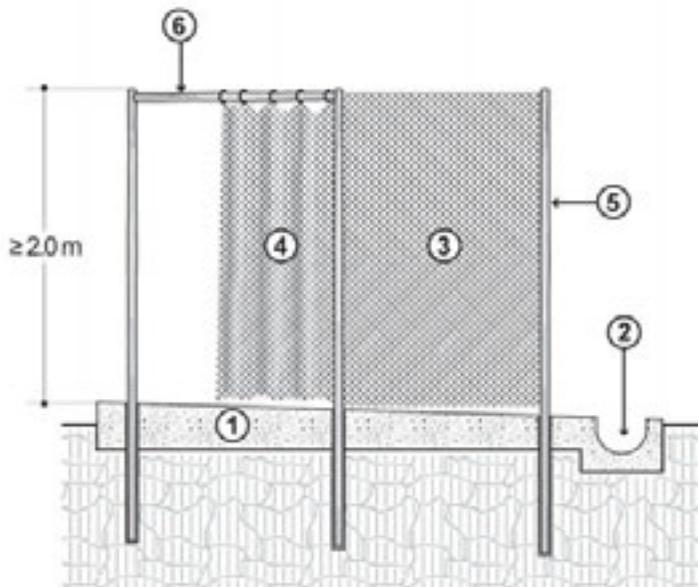
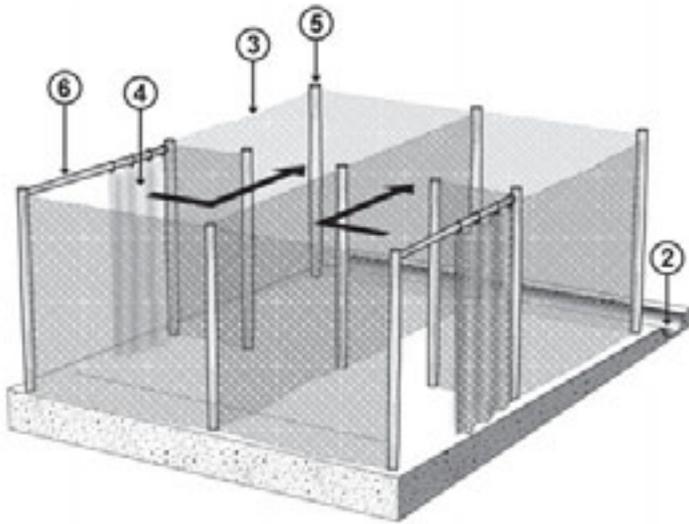
General hygiene is important to reduce certain diseases, and thus morbidity and even mortality. Showers should provide a hygiene facility for the beneficiaries without creating environmental health risks (e.g. stagnant water). They should be built close to a water point and their design should be adapted to the habits of the users (bucket shower, overhead shower). Proposed hereafter is just one possible model, mainly for emergencies.

Construction

- Choose a site in the neighbourhood of dwellings / (health structure) buildings and close to a water point. The site should have enough space and capacity to infiltrate wastewater (T.B. 4.05).
- Prepare the site for construction: remove all debris, flatten the surface, install a temporary fence and bring in the needed construction material and equipment.
- Lay out the area with dimensions of at least 2.5 m x 2.2 m, using string lines. This size will permit to build a double shower, with a drainage channel included at the back.
- Excavate from this area all soil containing dust, hidden debris and decomposing vegetation (humus), and dig a little deeper at the back to prepare the open drainage channel.
- Make holes of another 0.4 m deep nearby the corners and in the middle of the area, with a snail house shape as indicated on the figure.
- Anchor plastic pipes in the holes, sticking vertically out of the ground by at least 0.3 m. These holes will facilitate the insertion of the superstructure poles in a later stage.
- Construct a casing for the slab and drainage channel, at least 0.1 m above the ground level. An alternative is to use only the excavation as casing and to build protective kerbs afterwards on the edges of the slab and drainage channel.
- Prepare the excavated area for the concrete to be cast. In case of:
 - an unstable ground, spread a layer of sand and gravel on the whole area and compact it well.
 - a stable but permeable ground, put a piece of plastic sheeting on the whole excavated area, including its edges and the casing.
 - a stable and impermeable ground, no specific features need to be foreseen.
- Prepare and cast lean concrete (150 kg/m³; T.B. 2.05) to form the slab and the drainage channel. The concrete should be vibrated to remove all oxygen. Once the concrete starts to settle, create for the slab a slope of 1 to maximum 4% towards the open drainage channel, needing itself a perpendicular slope of 1.5%. Try to obtain a smooth surface because it will help to drain the wastewater away. However, the slab should not become slippery as this could lead to accidents.
- Cover the slab and drainage channel with thick sacking that is regularly wetted or with plastic sheeting (that will keep the humidity inside), and let it cure for at least 1 week.
- Connect the shower via a grid and a grease trap (T.B. 4.04) to an infiltration system like a soak away pit (T.B. 4.06), an infiltration trench (T.B. 4.07), an evapo-transpiration area (T.B. 4.08) or a closed sewer system.
- Make a superstructure with poles and plastic sheeting or waterproof local material. It is strongly recommended to install a roof over the showers with separate drainage to avoid too much rainwater evacuating via the grease trap and infiltration system, which will eventually lead to their breakdown. If the separate drainage is extended around the structure, runoff water can be evacuated without eroding the showers.
- Fence off the area with a permanent structure to protect it against animals.

Maintenance

- Make sure that the concrete slab and the superstructure of the showers are cleaned and disinfected with 0.1% chlorine solution (T.B. 2.20) every day.
- Make sure that the grid retaining solids from going into the grease trap and infiltration facilities is checked / cleaned on a daily basis.
- Make sure that the grease trap is maintained on a weekly basis (T.B. 4.04).



Key	Input
1. Shower slab (1 to max 4% slope)	- Shovels, hoes and pick
2. Drainage channel (1.5% slope) leading via a grate and grease trap to an infiltration / disposal system	- String line, sticks and tape measure - Spirit level - Plastic sheeting or jute sacking
3. Superstructure (e.g. non-transparent plastic)	- Sand, cement and gravel
4. Entrance of the shower (curtain)	- Clean water
5. Strong poles (possibly connected diagonally)	- Casing material (wooden planks)
6. Curtain support	- Trowel, float, long flat lath - Plastic pipes (PVC) - Poles, plastic sheeting or local waterproof material
<i>Dimension (in m) is indicative and has to be adapted according to the context</i>	- Big and small hammer - Nails and rope - Temporary and permanent fence material

Remarks

- Several of these shower constructions can be put in rows. The amount of showers needed depends on the number of potential users (1 shower / 40 persons; T.B. 1.08; 1.09).
- The location of the shower unit should not be too remote from the dwellings / (health structure) buildings, to increase the comfort but even more to reduce potential sexual violence. The location should also permit to enter the shower in a discrete manner (e.g. not in the middle of a public court).
- An additional non-transparent screen in front of the entry side of the showers improves the privacy, which might lead to a more frequent use of the facilities. In certain cultures, the use of showers might drastically increase when they are integrated within a comfort zone together with latrines and washing facilities for sanitary towels. In other places, it might be better to keep the showers completely separated from the latrines, to avoid confusion in their use.
- Also for privacy purposes, avoid elevated areas (e.g. heaps of excavated soil) nearby the showers.
- It is also important in most cultures to have separated shower facilities for men and women. It is strongly recommended to have separated showers as well for the staff in health structures.
- In all cases, the showers should be adapted to the habits (e.g. bucket shower, overhead shower with running water) and the average height of its users. In case of overhead showers with running water, be aware that the water consumption will increase drastically, meaning that the capacity of the wastewater facilities will have to be adapted as well.
- Special attention should go as well to showers for physically impaired people. The water supply should be close to the showers and easy accessible. More space, a seat and handle bars should be available. It is recommended that in-patient health structures have such adapted shower facilities.
- For hygienic reasons, it should be avoided that showers are used for washing laundry or dishes.
- The slab and drainage channel can also be made with bricks that are covered with cement plaster (T.B. 2.05), but this construction is generally less strong than concrete.
- The curing of the slab is important to obtain its strength (T.B. 2.05).
- It is recommended to install a hook within the superstructures to allow users to hang up their clothes.
- In places where people defecate in the showers, the bottom of the superstructure panels could start just above ankle height (about 0.2 m) to avoid people squatting down. This system cannot be used in all cultures, which has to be verified during the assessment.
- A good drainage with grid, settlement tank with grease trap and disposal / infiltration system is essential to avoid the shower area to become a puddle of stagnant water and thus a potential health hazard.
- Plastic bags are often used to transport the soap for washing. These bags are often discarded in the drainage system, which will clog up. To reduce this risk, a waste bin needs to be installed nearby the shower and its purpose explained to the users. Do not forget to empty and maintain the bin.
- Soap and buckets should be supplied to allow people to wash themselves.
- In certain countries, the shower might be replaced by a sauna (beyond the scope of these guidelines).

T.B. 4.02 Washing facilities

A washing area should provide a hygiene facility to do the laundry or the dishes, without creating environmental health risks (e.g. stagnant water). Its design should be adapted to the habits of the population, particularly concerning the position generally used by women to wash clothes or dishes (e.g. crouching or standing up). The facility described here is about the simplest possible to build.

Construction

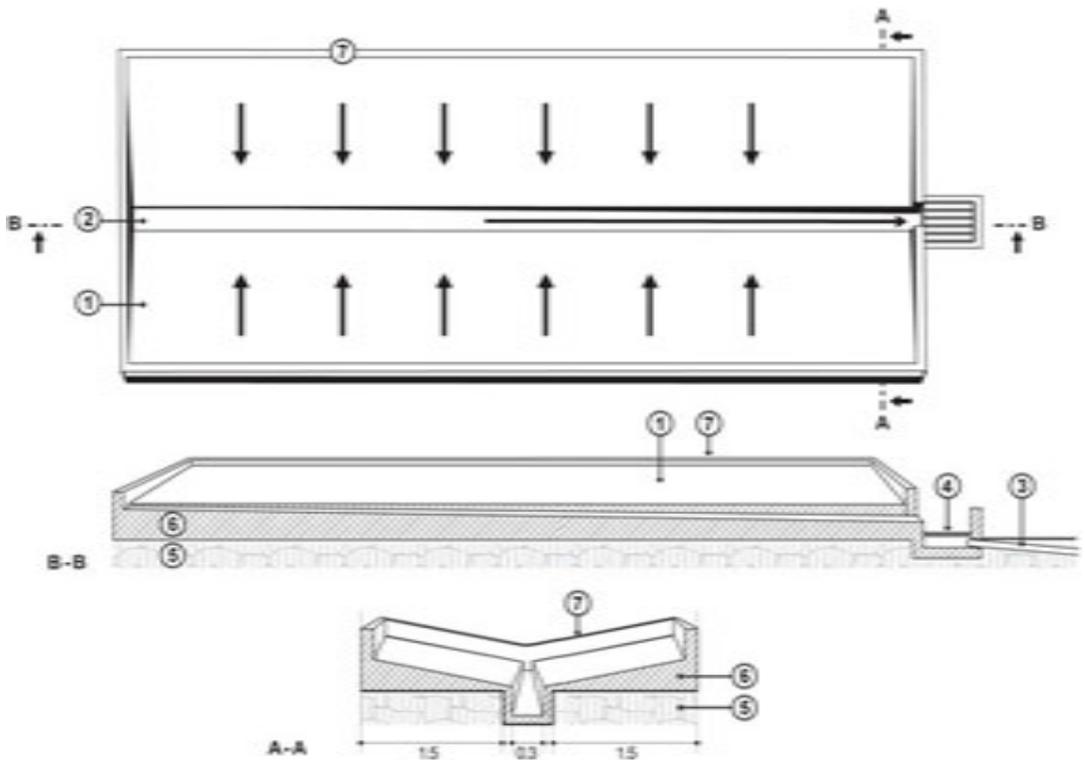
- Choose a site in the neighbourhood of the dwellings / (health structure) buildings and close to a water point. The site should have enough space and potential to infiltrate wastewater (T.B. 4.05).
- Prepare the site for construction: remove all debris, flatten the surface, install a temporary fence and bring in the needed construction material and equipment.
- Lay out the area using a string line. An area of 1.5 m x 1 m must be considered as the minimum space needed for one user doing the laundry. A larger width will raise the comfort for the individual user, whereas the total length is linked with the potential number of persons using the facility at the same time. Be aware however that the bigger the size of a concrete slab, the higher the risk of cracking. So it is better to construct several washing facilities of reasonable size (e.g. 4 m length) instead of a huge one.
- Excavate from this area all soil containing dust, hidden debris and decomposing vegetation (humus).
- Prepare the excavated area for the concrete to be cast. In case of:
 - an unstable ground, spread a layer of sand and gravel on the whole excavated area and compact it well.
 - a stable but permeable ground, put a piece of plastic sheeting on the whole excavated area, including its edges.
 - a stable and impermeable ground, no specific features need to be foreseen; except if the excavated area is deep and requires some backfilling with a compacted layer of sand and gravel.
- Prepare and cast lean concrete (150 kg/m³; T.B. 2.05) to form the double sloped slab and the drainage channel. The concrete should be vibrated to remove all oxygen. Once the concrete starts to settle, create slopes of maximum 4% along the whole area's length, both leading to the drainage channel in the middle, needing itself a perpendicular slope of 1.5% (the direction of all slopes are indicated by the arrows on the figure). Try to obtain a smooth surface because it will help to drain the wastewater away. However, the slab should not become slippery as this could lead to accidents.
- Cover the whole slab with thick sacking that is regularly wetted or with plastic sheeting (that will keep the humidity inside) and let it cure for at least 1 week.
- Construct on the circumference of the concrete slab a protective kerb with fired bricks or cement blocks, leaving an opening at the level of the drainage channel. The protective kerb should rise at least 0.1 m above the ground level.
- Construct a simple and open collection box (T.B. 4.03) at the end of the drainage channel.
- Cover all the surfaces of the protective kerb and collection box) with two layers of cement plaster (each 10 mm thick; T.B. 2.05), and smooth it well. Let it cure for several days, preferably a week.
- Connect the collection box of the washing facility via a grease trap (T.B. 4.04) to an infiltration system like a soak away pit (T.B. 4.06), an infiltration trench (T.B. 4.07), an evapo-transpiration area (T.B. 4.08), or a sewer system. To avoid the connection pipes in between the wastewater facilities getting blocked with big (waste) fragments, a grid should be installed inside the collection box.
- Install preferably a roof over the washing facility with a rainwater harvesting system (T.B. 2.09) and/or a separate drainage to avoid too much runoff water evacuating via the grease trap and infiltration facility, which will eventually lead to their breakdown. If the separate drainage is extended around the structure, runoff water can be evacuated without eroding the washing facilities.
- Fence off the area to protect it against animals.

Maintenance

- Make sure that the slab of the washing facilities is cleaned and disinfected with 0.1% chlorine solution (T.B. 2.20) every day.
- Make sure that the grid retaining solids from going into the grease trap and the infiltration facilities is checked / cleaned on a daily basis.
- Make sure that the grease trap is maintained on a weekly basis (T.B. 4.04).

Key	Input
1. Washing slab (sloping towards drainage channel, maximum 4%)	- Shovels, hoes and picks
2. Drainage channel (1.5% slope)	- String line, sticks and tape measure
3. Drainpipe towards grease trap and final disposal	- Spirit level
4. Collection box with grid	- Plastic sheeting or jute sacking
5. Soil (possibly covered with sand / gravel or plastic)	- Sand, cement and gravel
6. Lean concrete slab	- Clean water
7. Protective kerb	- Fired bricks or cement blocks
	- Trowel, float, cement-mixing trough
	- Roof material and tools
	- Temporary and permanent fencing material

Measurements (in m) are indicative and have to be adapted according to the context.



Remarks

- The location of the washing facilities unit should not be too remote from the dwellings / (health structure) buildings to increase the comfort, but even more to reduce the potential sexual violence.
- If people prefer to wash clothes standing up, a raised concrete tub that can easily be emptied, or a raised slab (e.g. at table height) is required. Clothes or dishes are also sometimes washed within a basin or a 200 l drum cut in half.
- The number of washing facilities needed depends a lot on the habits of the users. It is also strongly recommended that every health structure has a washing facility.
- Special attention should go to the design of washing facilities used by pregnant women or/and (temporary) disabled people. Often, they won't be able to crouch down, so (slightly) raised facilities (attention to the height) with the possibility to sit down, potential handle bars and sufficient space might in some cases be needed.
- Although similar facilities can be used for washing clothes or cleaning the dishes, it's strongly recommended to separate both activities completely. Dirty clothes can contain faecal material, and are therefore incompatible with eating utensils.
- The slab and drainage channel can also be made with bricks that are covered with cement plaster (T.B. 2.05), but this construction is generally less strong than concrete.
- The curing of the slab is important to obtain its strength (T.B. 2.05).
- A good drainage with grid, grease trap and disposal / infiltration system is essential to avoid that the washing area becomes a puddle of stagnant water.
- In low-income countries, the cooking pots are quite often cleaned with sand / earth and water. To avoid the risk that the drainage / infiltration system blocks rather rapidly, a grease trap with integrated settlement tank is recommended. This can easily be obtained by making a standard grease trap bigger (standard size calculated according the maximum hourly flow of wastewater; T.B. 4.04). Mainly its depth will have to be increased to raise its storage capacity for the sand / earth.
- Plastic bags are often used to transport the soap for washing. These bags are often discarded in the drainage system, which will clog up. There is also the risk that food residues will be disposed of in the drainage. To reduce these risks, a waste bin needs to be installed nearby the washing area and its purpose explained to the users. Do not forget to empty and maintain the bin.
- Drying lines should be part of the washing areas in health structures. This helps avoiding people lying clothes on the ground to dry. A roof should be installed above the drying lines, certainly during the rainy season. It is also strongly recommended that where possible, the clothes and linen are ironed before being used again (e.g. for protection against Myasis).
- Soap and buckets might have to be supplied to allow people to improve their hygiene.
- During the acute phase of an emergency in a camp, it is possible to make washing areas by using only plastic sheeting (the same as being used for temporary shelters). The ground surface within a shallow excavation must be carefully prepared and all sharp objects (e.g. stones, roots) removed. A sand – gravel mixture compacted within the excavation provides the slopes for the working surface and drainage channel. These slopes should be lined with a double thickness of plastic sheeting. The edges of the plastic should be fixed with stones and covered with well-compacted earth. This technique only lasts a few days because the plastic sheeting gets damaged very quickly and/or might get stolen.

T.B. 4.03 Manhole / Collection - Distribution box

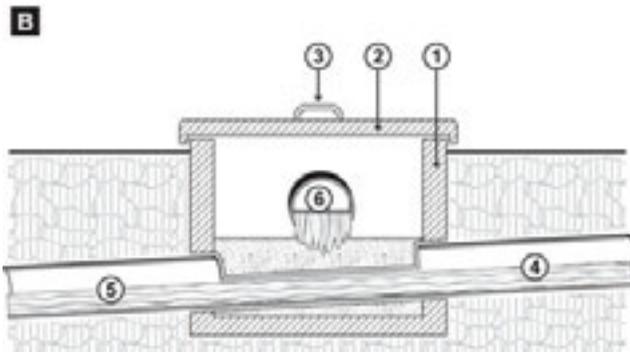
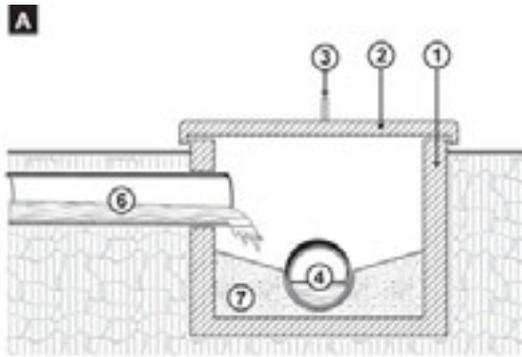
Manholes permit to verify the correct functioning of underground wastewater pipes, and potentially to unplug them. A manhole is usually foreseen at every 10 to 15 m length of pipe and at each crossing and/or sideways connection of pipes. Collection boxes are needed to bring wastewater coming from different directions together in one evacuation pipe, and should allow as well an internal check of the underground disposal system. Distribution boxes are similar to collection boxes, but their design with multiple evacuation pipes at the bottom leads the wastewater away towards different directions. They all need to be maintained and cleaned at least once a month.

Construction

- Foresee extra space for manholes / collection-distribution boxes at the described places, while digging the trenches for a piped wastewater evacuation and dispersal system. The size of the extra excavation depends on the depth of the piping system. The deeper the pipes, the deeper and also the wider the manhole / collection-distribution box (for people to enter completely) and thus their excavation need to be. This means also a serious increase in costs. The minimum operational inner size is 0.60 m x 0.60 m, to allow entering a device to unblock the system.
- Build the manholes / collection-distribution boxes out of concrete or masonry-work (fired bricks, cement blocks or stones according to what is available) and foresee holes for the pipes. The bottom of the manholes / collection-distribution boxes must be constructed with a gradient equal to the slope of the pipes they will be connected to (at least 1%), and have a shape that helps to lead the wastewater into the evacuation pipes.
- Install the pipes (diameter of at least 100 mm) in the manholes / collection-distribution boxes. Each evacuation (outlet) pipe should be at the same level as the bottom of their respective manhole / collection-distribution box.
- Make each manhole / collection-distribution box as watertight as possible by covering all its inner and outer surfaces with cement plaster (T.B. 2.05), and give particular attention to the pipes passages. For the outer surfaces, only one 10 mm layer is required, whereas internally it is recommended to add a second 10 mm layer once the first one has dried. Smooth the second inside layer well because this will ease the maintenance afterwards.
- Install a solid (watertight) lid on each manhole / collection - distribution box to avoid access to vectors.
- Backfill the space in between each manhole / collection - distribution box and its respective excavated hole with compacted soil.

Remarks

- Make sure to install a temporary fence around the works to avoid accidents.
- Avoid having an evacuation pipe higher than the bottom of its manhole / collection-distribution box because it will produce stagnant water and dry blockings if the water would evaporate.
- Installing a complete pipe through the manhole / collection box, with its upper half been cut out at the section where it passes the box (see drawing), is a good alternative because it simplifies the works to make the construction watertight.
- Be aware that a concrete lid of 0.80 m x 0.80 m x 0.07 m weighs about 95 kg. For the maintenance to be done regularly (e.g. once a month), it's important that the lid has good handles and isn't too heavy (maximum 50 kg if it is to be opened by a single maintenance person). It's recommended for big concrete lids to make them in several parts or to choose a lighter but still solid and watertight material.
- In the first phase of an emergency, manholes and collection-distribution boxes can also be made out of 200 l drums. The recommendations for normal manholes and collection boxes (e.g. the position of the evacuation pipe, the shape of the bottom and sealed pipe entrances) are also valid for temporary models.
- The manhole construction can also be used in (potable) water systems to render the valves and connections protected and accessible. Provide the lid of the manhole with a padlock to avoid that people would fiddle with the valves.



Key

Input

- A. Front view of a collection box
 B. Side view of a collection box

1. Watertight casing
2. Removable lid (each element < 50 kg)
3. Handle
4. Incoming pipe A
5. Outlet pipe
6. Pipe B* (represented here as an incoming pipe)
7. Cemented slope

- Detailed construction plans
- Cement, sand, gravel, clean water
- Shuttering timber (for concrete)
- Bricks / blocs / stones
- Masonry tools
- 6 mm reinforcing bars (lid)
- Shovel, hoe, pick, miner's bar
- Pipe: (min. diameter 100 mm PVC pipe)
- Temporary fence material

- *: - When pipe B isn't located at the bottom of the box (as indicated on the figure), it's an incoming pipe, and the facility functions like a collection box.
 - When pipe B is located at the bottom of the box, it's an outlet, and the facility functions like a distribution box (e.g. infiltration trenches; T.B. 4.07 and evapo-transpiration area; T.B.4.08).
 - If there is no pipe B, the facility functions as a manhole.

T.B. 4.04 Grease trap

A grease trap is used for separating oil, fat and some solid materials from the wastewater before its disposal in the ground, or even in a sewer system. If oil, grease and solid materials are left in the effluent, they very quickly clog an infiltration system.

Principle

Two simple types of grease traps may be distinguished, and the choice between one of them will often be decided by the materials and skills available:

- With an elbow at the inlet and a “Tee” at the outlet (easiest solution; “A type” on the figure)
- With separating partitions until the bottom (better retrieval of solid material; “B type” on the figure).

Any grease trap operates with three zones:

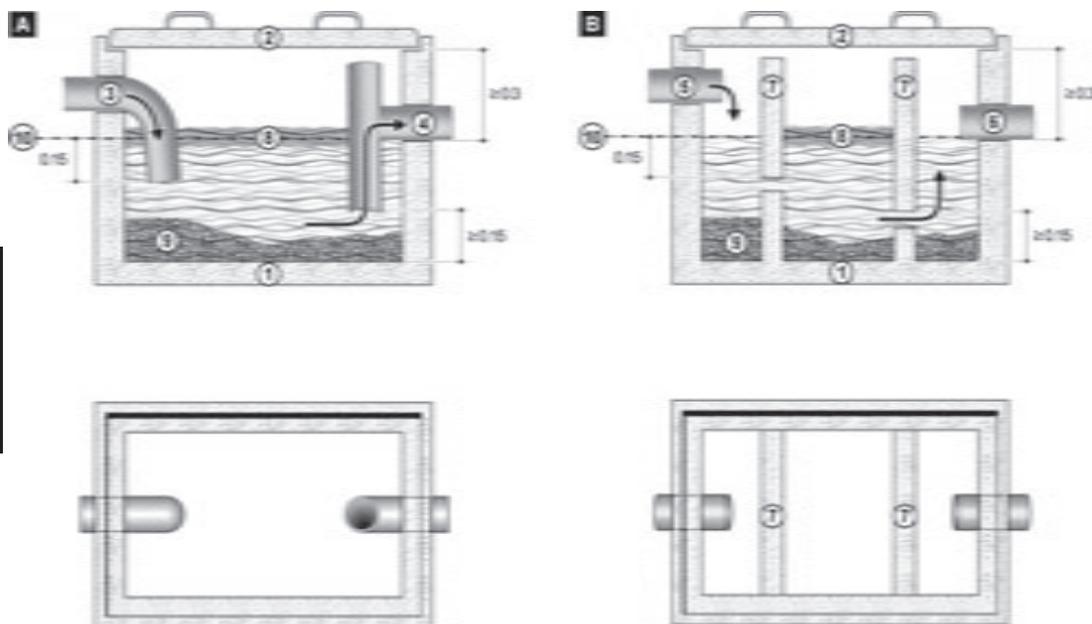
- An inlet zone that slows down and distributes the effluent in the trap;
- A middle zone where fatty material floats and accumulates at the surface, and where heavier solids settle to the bottom;
- An outlet zone where grease-free water flows out towards the underground dispersal system or the underground sewer system.

Construction

- Choose a place as close as possible to the site where the wastewater is generated, with easy access and in front of the dispersal system: soak away pit (T.B. 4.06), infiltration trench (T.B. 4.07), evapo-transpiration area (T.B. 4.08) or sewer.
- Design the grease trap and draw a detailed plan. It should be rectangular in shape with its in- and outlet as far as possible from each other. The effective volume of the grease trap (volume actually filled with wastewater) should be enough to allow a sufficient retention time of the wastewater for the oil and fat to be separated, and for the solids to settle. As a general rule, consider that the effective volume should at least be double the maximum hourly flow entering the trap; e.g. for 100 l of wastewater entering per hour during the peak moment, the effective volume of the grease trap should be at least 200 l.
- Prepare the site for construction: remove all debris, lay out the area, install a temporary fence and bring in the needed construction material and equipment.
- Excavate at the chosen place, along the evacuation pipe trench, the area for the grease trap. The excavation dimensions must be bigger than the size of the grease trap to be built.
- Build the grease trap using locally available means and materials like cast concrete or masonry-work (fired bricks, cement blocks or stones), and foresee openings for the pipes. Make sure that the casing sticks out of the ground by at least 0.1 m to avoid runoff water entering the grease trap.
- Position the inlet and outlet pipes (diameter of at least 100 mm) carefully in order to facilitate the flow and the operation of the trap (see drawings).
- Make the grease trap as watertight as possible, by covering all its inner and outer surfaces with cement plaster (T.B. 2.05), and give particular attention to the pipe passages. For the outer surfaces, only one 10 mm layer is required, whereas internally it is recommended to add a second 10 mm layer once the first one has dried. Smooth the second inside layer well because this will ease the maintenance afterwards.
- Install a removable cover, equipped with handles. It should fit well on the trap and have a certain weight to avoid unauthorized opening (by children for instance), but still light enough to be opened regularly by a single maintenance person (maximum 50 kg).
- Backfill the space in between the grease trap and the excavated hole with compacted soil.
- Dig trenches around the grease trap to lead also the runoff water away.

Maintenance

- Make sure that the fat, grease and oil are removed from the grease trap on a weekly basis.
- Bury the grease layer or possibly discard it in the residues pit in case of a health structure.
- Don't forget to remove once in a while also the solids that have settled on the bottom of the grease trap. To ease this maintenance, a pump capable of pumping solids (e.g. motor pump, dewatering pump) and a recipient (e.g. bladder) can be used. This pump and the recipient can never be used anymore for potable water!



Key

Input

- A. Model with elbow and tee
B. Model with baffles

- | | |
|--|---|
| 1. Watertight casing | - Detailed construction plans |
| 2. Removable lid with handles (each element < 50 kg) | - Fired bricks or cement blocks / concrete |
| 3. Inlet elbow, 90° | - Cement, sand, (gravel), clean water |
| 4. Outlet tee | - Shuttering timber |
| 5. Inlet | - Reinforcing bars (6 – 8 mm) |
| 6. Outlet | - Shovel, hoe, pick and miner's bar |
| 7. Separating partitions (baffles) | - Masonry tools |
| 8. Middle zone (separation of fat, grease and oil) | - Minimum 100 mm PVC pipe, or elbow and Tee |
| 9. Settled solids | - Cover (e.g. concrete, metal, solid plastic) |
| 10. Reference line indicating effective depth (max. water level) | - Temporary fence material |

Measurements are indicated in m

Remarks

- Even in situations where a (closed) sewer system exists, wastewater (grey and black) should be pre-treated before being released (at least respectively by a grease trap or a septic tank).
- Runoff water should never pass through the grease trap because it isn't needed (contains normally no oil, grease or fat), and its effective volume would need to be huge to obtain a sufficient retention time for the high quantity of diluted wastewater.
- Concrete covers of grease traps are often a lot heavier than 50 kg, which explains partly why these facilities aren't well maintained. If concrete is used for the cover, the grease trap should be designed in such a way that the lid is divided in several parts, but still closes tightly to avoid vectors entering. Other lighter and resistant materials like metallic sheets (treated against rust), aluminium or plastic should also be considered for the cover of the grease trap.
- The "B type" partition baffles help to reduce the amount of settled materials escaping from the grease trap. The (PVC) pipes passing through, or the honeycombed part in the partitions should be at least 100 mm above the bottom of the grease trap.
- Good maintenance is the key to an effective grease trap as it will limit odours and avoid fat and oil getting into the infiltration / sewer system.
- The oil and fat coming out of a grease trap should never be disposed of in an organic waste pit or a latrine. They would clog the vertical infiltration walls of the pit, therefore obstructing the liquids to infiltrate into the ground.
- To be able to perform the maintenance correctly, the staff needs protective clothing such as (watertight) heavy-duty rubber gloves, overall, mask, boots and other material such as collection and transport recipients, a pump, a wheelbarrow and shovels.
- The maintenance team should be able to recognize when a grease trap doesn't function properly. Some indicators can be:
 - soapy water enters the infiltration system (e.g. to be seen at its distribution box).
 - infiltration system starts to overflow (although other reasons can be the cause as well).
 - grease trap overflows (possibly due to bad maintenance or a wrong design).
- In emergency situations and where the amount of wastewater is very limited (peak flow < 50 l/h), a grease trap can be constructed out of a 200 l drum, an elbow and a T-piece (according to the "A type").
- Grease traps can also be made out of rectangular plastic containers, or even bought ready-made (importation probably needed).

T.B. 4.05 Soil stability and permeability tests

The surface of the Earth consists of consolidated (stone / rock formations) and unconsolidated (soil) material; the latter being categorised in numerous soil textures. A precise description of the numerous textures is beyond the scope of this manual. However, every texture has its own stability, which has its influence on the lifespan and stability (risk of collapse) of ground works like for latrines and waste pits. Texture tests allow the estimation of the soil stability. All soil textures also have their own permeability, influencing the infiltration capacity. The measurement of the soil permeability by means of percolation tests allows:

- the estimation of the infiltration capacity of a soil to be used for the dispersal of effluents;
- the potential sizing of a dispersal system.

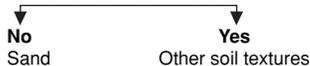
Soil texture test

Soil texture is the relative proportion in percentage of sand, silt and clay-sized mineral particles in the fine-earth fraction of the soil. The physical properties of soils depend largely on their texture: e.g. sand is gritty and has very good drainage capacities, but it is unstable with regards to excavations; clay feels slick and sticky, and exhibits plasticity when mixed with water, to which it is relatively impermeable, but it is stable against collapse when dry; silt feels smooth and velvety (like flour). Loams are composed of sand, silt and clay, in different proportions, having an influence on their properties (e.g. water retention, plasticity, permeability).

The soil texture can be determined on the field with the following test (adapted from Lindbo et al.):

- Humidify the soil enough to be able to mould it like putty, but without saturating it.

- Can a ball be made of the soil?



- When pressing the ball between thumb and forefinger, does the soil form a ribbon that extends beyond the forefinger?



- Is it possible to make the ribbon longer than 25 mm before it breaks?



Wet a small sample of the ribbon excessively in the hand palm and rub it with the forefinger. If it feels:

gritty → Sandy loam
smooth → Silt loam
neither → Loam

- Is it possible to make the ribbon longer than 50 mm before it breaks?



Wet a small sample of the ribbon excessively in the hand palm and rub it with the forefinger. If it feels:

gritty → Sandy clay loam
smooth → Silty clay loam
neither → Clay loam

Wet a small sample of the ribbon excessively in the hand palm and rub it with the forefinger. If it feels:

gritty → Sandy clay
smooth → Silty clay
neither → Clay

Percolation test

Although the determination of the texture gives already an indication on the permeability of the soil (see table hereafter), it is recommended to do a percolation test as well.

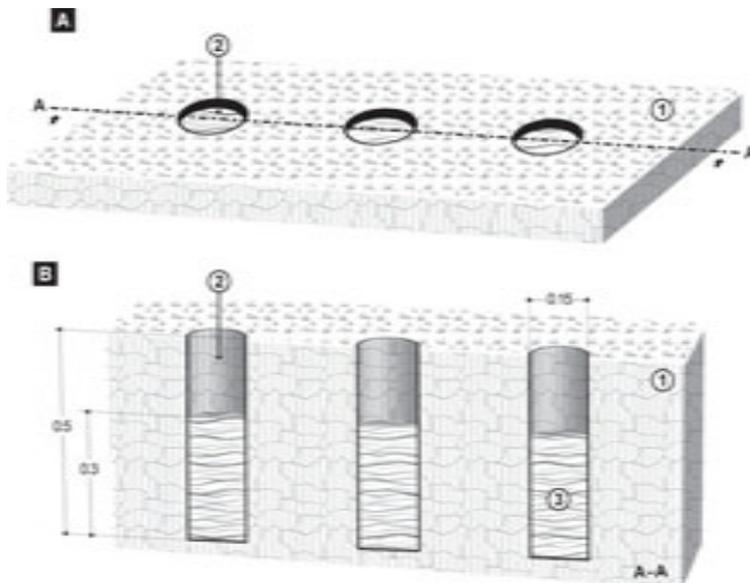
- Make at least 3 test holes, each one with a diameter (D) of 0.15 m and 0.5 m deep on the proposed site.
- Fill the holes completely with potable water and leave overnight (or at least for several hours) to bring the soil to a saturated state.
- Fill the test holes the next day with potable water to a height of 0.3 m (if the water levels in the holes are still at or above 0.3 m height overnight, the permeability will certainly be too low for infiltration systems).
- Measure the water levels in the holes after 30 minutes and again after 90 minutes.
- Calculate the average difference in water levels of the three holes (h) corresponding to this period of 60 minutes, in order to determine the average water volume (Vav) that has been infiltrated per hole:

$$V_{av} (l) = 3.1416 \times D^2/4 (m^2) \times h (m) \times 1000$$

- Extrapolate this average infiltrated water volume per hole (vertical infiltration area of about 0.15 m²) to an infiltration surface of 1 m² over a 24 hours period in order to obtain the infiltration rate in l/m²-day:

$$\text{Infiltration rate (l/m}^2\text{-day)} = V_{av} (l)/0.15 (m^2) \times 24 (\text{hours})$$

- Compare the result with the infiltration rate values of potable water for different soil textures represented in the table hereafter. Thus an indication for the infiltration rate of wastewater for this soil is obtained as well.



Key

1. (Permeable) soil at the site proposed for a dispersal system
2. Test holes (diameter = 0.15 m, depth = 0.50 m)
3. Test holes filled with 0.30 m of water

Input

- 1 operator
- 1 hand auger or pick and shovel
- 1 watch or stopwatch
- 1 tape measure

Measurements are indicated in m

Formulas

$$\text{Effective infiltration surface (m}^2\text{)} = \frac{\text{Volume of effluent to be infiltrated (l/day)}}{\text{Soil infiltration rate (l/m}^2\text{-day)}}$$

Soak away pit (round model) (T.B. 4.06)

In case the water table level isn't a limiting factor for the design of a soak away pit, its diameter can be chosen and thus the minimum depth calculated. It is recommended however for safety reasons that an unlined soak away pit doesn't exceed a depth of 2 – 3 m (depending on the soil texture).

$$\text{Depth of soak away pit (m)} = \frac{\text{Effective infiltration surface (m}^2\text{)}}{3.1416 \times \text{pit diameter (m)}} + 0.5 \text{ m}$$

The 0.5 m is the estimated depth of the pipe outlet and the surface above isn't effective for infiltration. This supplementary depth might have to be adapted to the real depth of the pipe outlet.

If the water table level is relatively high and represents thus a limiting factor for the soak away pit's depth, the diameter will have to be adapted to the maximum depth that can be admitted. Make sure that the bottom of the soak away pit is always at least 1.5 m above the highest water table level (rainy season). Following formula can be used:

$$\text{Diameter of soak away pit (m)} = \frac{\text{Effective infiltration surface (m}^2\text{)}}{3.1416 \times (\text{max. pit depth} - 0.5) \text{ (m)}}$$

The 0.5 m is the estimated depth of the pipe outlet and the surface above isn't effective for infiltration. This supplementary depth might have to be adapted to the real depth of the pipe outlet.

Infiltration trench (T.B. 4.07)

Once the effective infiltration surface is known, the length of infiltration trenches can be calculated:

$$\text{Length of infiltration trench (m)} = \frac{\text{Effective infiltration surface (m}^2\text{)}}{2 \times \text{effective depth of trench below drain pipe (m)}}$$

The effective depth is the infiltration height underneath the perforated pipe. The bottom of the trench should be at least 1.5 m above the highest water table.

Example of dimensions of a dispersal system

The effluent of the septic tank of a health centre must be eliminated with infiltration trenches.

- The effluent volume to infiltrate is 500 l/day.
- The infiltration rate of the soil is estimated at 10 l/m²-day.
- The trenches will have an effective depth of 0.5 m.

- The effective infiltration surface is calculated according to the following way:

$$\frac{\text{Volume of the effluent (l/day)}}{\text{Infiltration rate (l/m}^2\text{-day)}} = \frac{500}{10} = 50 \text{ m}^2$$

- A trench is made of two vertical walls; the total length of the trench is obtained by:

$$\frac{\text{Infiltration surface (m}^2\text{)}}{2 \times \text{effective depth (m)}} = \frac{50}{2 \times 0.5} = 50 \text{ m}$$

At least two trenches of 25 m length will be required (the maximum length of a single infiltration trench is limited to 30m). An alternative is to make infiltration trenches with the typical trident form (T.B. 4.07); each trench with a minimum length of 17 m. Notice that only the vertical surfaces (and not the bottom) of the trench have been taken into account in the calculation of the infiltration surface.

Remarks

Soil texture test

- Each time a pit or trench has to be dug, soil texture tests should be performed to determine the risk of collapse. The soil texture might change as the excavation gets deeper. Therefore might it be necessary to repeat the soil texture test at different depths, certainly when the colour of the soil changes and/or when it feels differently. It is also recommended to do soil texture tests at different places along a trench excavation. The soil humidity also plays a role in its stability (the wetter, the faster it will collapse).
- Pits with a partial lining (T.B. 3.04) can be excavated in soils with sand or loamy sand textures to a depth of 2 m only, whereas the depth can be increased to 3 m in soils with mainly dry loam and/or dry clay textures.
- The table represents the approximate infiltration rate estimations of potable water and wastewater according to the soil texture:

Soil texture	Infiltration rate of potable water (l/m ² -day)	Infiltration rate of wastewater (l/m ² -day)
Sand and loamy sand	2400 – 720	50 – 33
Sandy loam and loam	720 – 480	33 – 25
Sandy clay loam, silt loam, clay loam, silty clay loam and silt	480 – 120	25 – 12
Sandy clay, silty clay and clay <i>Clay is not suitable for soak away pits or infiltration trenches</i>	120 – 24	16 – 4 <i>Adapted from Lindbo et al.</i>

Percolation test

- This method of evaluating the soil permeability depends very much on the homogeneity of the soil. Therefore, a single percolation test has to be taken with precaution, as its results might not always represent the reality. It is advised to perform several percolation tests over the foreseen length of long trenches. As the excavation progresses, a number of percolation tests should also be done at different depths, certainly when the colour of the soil changes and/or when it feels differently. However, as such a test is quite time consuming, it isn't required for pits constructed during acute emergencies.
- As the percolation test is done with potable water, it does not take into account the clogging effect of the discharge of effluents carrying solids. Even spilled water at water points where there aren't washing activities will contain some solids. But in general, the soil may be considered as having a sufficient infiltration rate for a dispersal system if the level in each hole of the percolation test falls at least by 0.10 m during the 60 minutes period.
- It has been found that in the long run, the infiltration rate for different soil textures is more or less the same once the soil surface is partially clogged. To be on the safe side, it's better to work on the basis of 10 l/m²-day for the infiltration of wastewater effluents and 20 l/m²-day for water from a water point where no washing activities are done (e.g. tap stand).
- Be aware that the greater the permeability of the soil (good infiltration), the higher the risk of the wastewater contaminating the (ground)water. This should be taken into account for the vertical distance in between the bottom of pits / infiltration systems and the groundwater table. For homogeneous soils, the minimum vertical distance should be at least 1.5 m. It is also recommended as a general rule to install pits / infiltration systems downhill from groundwater points at a minimum distance of 30 m. This is to prevent microbiological contamination of the groundwater if wastewater would infiltrate until the aquifer. The minimum distances (vertically and horizontally) are difficult to predict for fissured soils, unfortunately.
- It is important to know that when the infiltration capacity of an underground dispersal system (e.g. soak away pit, infiltration trenches) is calculated, only its vertical surfaces (and not the bottom) can be taken into account. This is due to a bacteria layer that will form rather quickly on the bottom of the dispersal systems, which will become impermeable after a while, and thus inhibit all infiltration.
- In case you would notice that your first infiltration facility doesn't function as predicted by the permeability test, do not hesitate to construct new ones with oversized dimensions or change the technique (e.g. evapo-transpiration; T.B. 4.08).

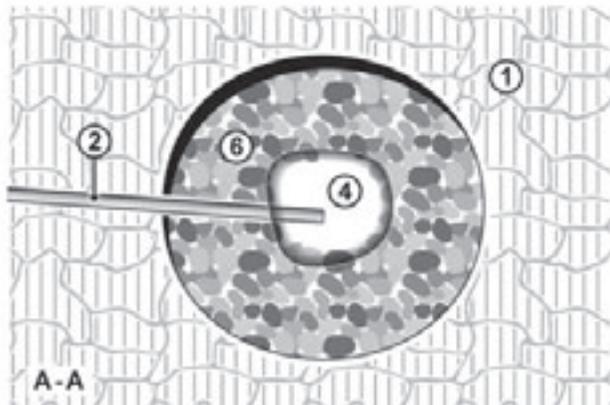
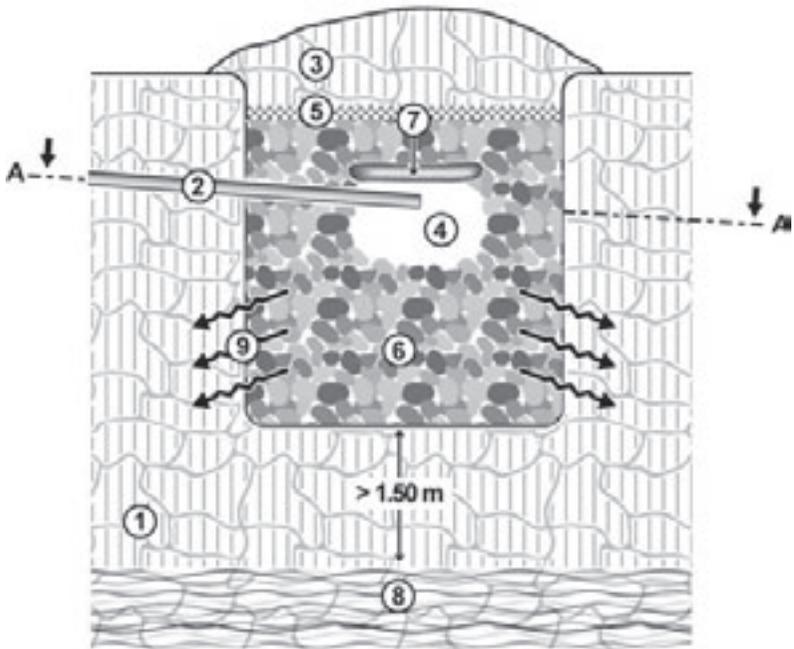
T.B. 4.06 Soak away pit

A soak away pit allows the disposal of a limited amount of wastewater from for instance a water point, kitchen or shower by infiltration into permeable soil, after having passed the necessary pre-treatment.

Construction

- Choose a site as close as possible to the grease trap, but at least 6 m from dwellings, 7.5 m from trees or hedges and 3 m from property boundaries. The site should preferably be downhill and at least 30 m away from (ground)water sources if it is a "domestic" soak away pit.
- Determine the dimensions of the soak away pit, based on soil texture and permeability tests (T.B. 4.05), the level of the water table and the quantity of wastewater to be infiltrated.
- Prepare the site for construction: remove all debris, lay out the area, install a temporary fence and bring in the needed construction material and equipment.
- Dig the trench for the incoming pipe, with a slope of at least 1%, 0.3 m wide and at least 0.3 m deep.
- Dig a circular pit to the required dimensions. Measure the effective depth from the bottom of the incoming trench until the bottom of the pit. If the pit is deep and/or the soil is unstable, support the sides with wooden planks and poles during the excavation.
- Fill the soak away pit with stones up to the level of the trench bottom. The stones should be clean, with a diameter of 0.05 to 0.15 m.
- Lay, potentially on a layer of sand, the incoming pipe (min. diameter 100 mm; at least 1% slope) until the middle of the pit. Clear the stones around the pipe end to create an empty space to aid flow dispersal.
- Place a large flat stone over the end (outlet) of the pipe and add a layer of stones (at least 0.1 m thick). If a flat stone can't be found, a concrete plate can be used as well.
- Cover the stones with geo-textile, or if not available, perforated plastic sheeting.
- Fill the hole with earth and compact it and plant grass on top if the water and/or wind erosion is severe.

Key	Input
1. Permeable soil	- Tape measure
2. Incoming pipe (min. diameter 100 mm)	- Shovels, hoes, picks and miner's bars
3. Compacted earth	- Wheelbarrow
4. Cleared space at the end of the pipe	- Pipe, minimum 100 mm diameter, in PVC or cement
5. Geo-textile or perforated plastic sheeting	- Geo-textile or plastic sheeting
6. Clean stones (boulders)	- Stones (0.05 – 0.15 m diameter)
7. Flat stone or concrete slab	- Temporary fence material
8. Water table	- Reinforcing bar or ½" galvanised pipe and hammer
9. Wastewater infiltrating in the soil	



Remarks

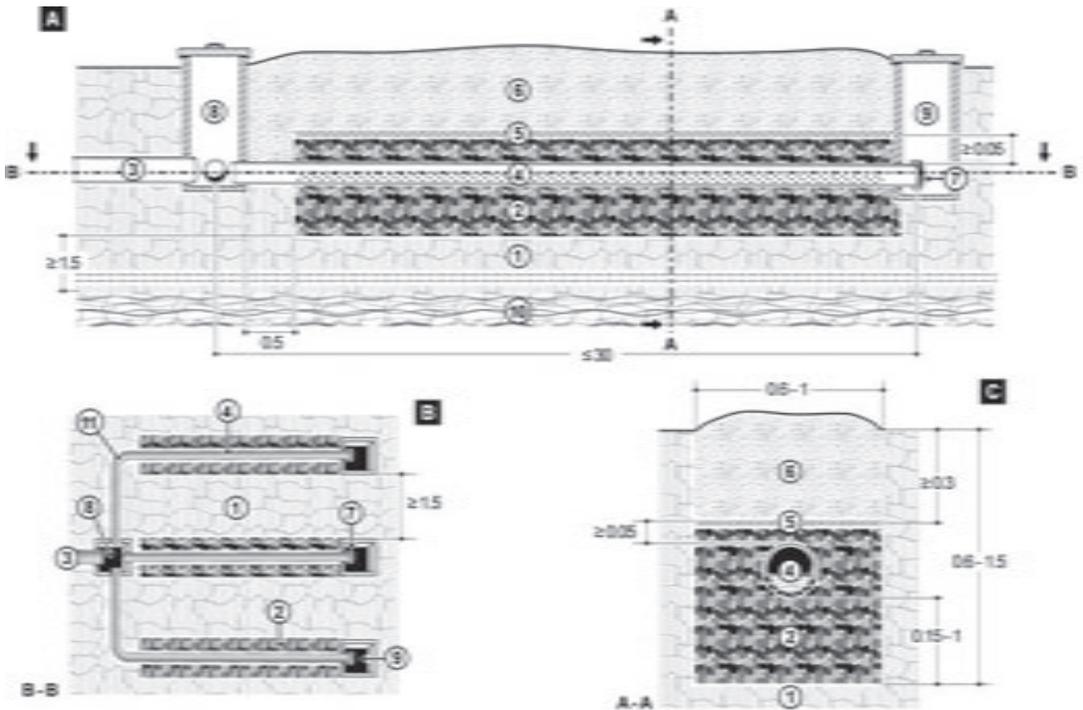
- Soak away pits can only infiltrate limited amounts of (pre-treated) wastewater. To determine the dimensions of the pit, it is important to evaluate the infiltration capacity of the soil and to allow for a possible increase in the amount of wastewater to be disposed of. Be aware that the infiltration will only take place via the vertical walls of the pit, thus its bottom should not be included as infiltration surface (due to an “impermeable” bacteria layer forming on the bottom).
- The bottom of the soak away pit should be at least 1.5 m (preferably 3.0 m if connected to a septic tank) above the highest possible water table (during the rainy season). If the groundwater table is rather high, opt for infiltration trenches (T.B. 4.07). The depth of the water table can be estimated by verifying its level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½” galvanized pipe in the ground, as deep as 1.5 m beneath the required pit depth. When pulled out, the rod or (the earth inside) the pipe should be dry. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level.
- Even with a water table that is always very deep, it is recommended to restrict the depth of a soak away pit (preferably to 3 m maximum) to limit the risk of collapse during the excavation works.
- If stones aren’t available for the reinforcement of the soak away pit, tree branches or bamboo can be used to construct a circular lining. But soak away pits made with these materials have a shorter lifespan (maximum 2 years), and are therefore only admissible during (the acute stages of) an emergency. Soak away pits are sometimes also lined with masonry-work or even concrete rings, with a concrete slab on top. Make sure that these models have enough holes in their lining to drain the liquids through their sides. Anyhow, their infiltration surface will be drastically reduced due to the lining. As these kinds of soak away pits are already a serious investment, infiltration trenches are probably a better option for sullage. Lined soak away pits can be a rather cheap alternative however for pour-flush toilets in comparison to a septic tank.
- There is sometimes a tendency not to cover the soak away pit with compacted earth, certainly in dry and hot areas. The idea is to use the heat of the sun assisting in the evaporation of the wastewater. Nevertheless, it is strongly recommended to cover the soak away pit as the geo-textile or perforated plastic sheeting over the stones prevents soil from getting between the stones and clogging the system, but still permitting air to get in and gasses to come out of the pit.
- A grease trap (T.B. 4.04) should be installed in front of the soak away pit when the wastewater originates from a kitchen, showers, a sink or a washing area, in order to avoid clogging by oil and fat.

T.B. 4.07 Infiltration trench

Infiltration trenches may be used for the underground dispersal of wastewater from for instance kitchens and health centres, after having passed the necessary pre-treatment. They may equally be used for disposing of effluents from septic tanks.

Construction

- Choose a site as close as possible to the grease trap, but at least 6 m from dwellings, 7.5 m from trees or hedges and 3 m from property boundaries. The site should preferably be downhill and at least 30 m away from (ground)water sources.
- Determine the dimensions of the trench or trenches according to the soil texture / permeability tests, the level of the water table and the quantity of wastewater to be infiltrated (T.B. 4.05).
- Prepare the site for construction: remove all debris, lay out the area with string line, install a temporary fence and bring in the needed construction material and equipment.
- Dig the trenches (about 0.3 m wide and at least 0.3 m deep) for the incoming pipe (at least 1% slope) and the union pipes to form the trident pattern for the drains (at least 1.5 m apart from each other).
- Dig the actual infiltration trenches to the required dimensions as indicated on the figure (with a slope of 0.2% to maximum 0.5%). The maximum length of a single infiltration trench is limited to 30 m, this to have a good wastewater repartition.
- Construct a distribution box at the end of the incoming pipe trench and potentially 3 manholes where the dispersal drain pipes will end (T.B. 4.03).
- Install the incoming pipe and the union pipes with elbows (min. diameter 100 mm) in the trenches, potentially on a layer of sand, and make the connections with the distribution box watertight.
- Rake the sides and bottom of the infiltration trenches. Do not walk in the trenches after this work.
- Fill the infiltration trenches with clean (uniform sized) gravel up to the level where the union pipes end, respecting the 0.2 – 0.5% slope (min. thickness of the gravel layer: 0.15 m, but preferably up to 1 m).
- Lay the drains (perforated / porous pipe, or pipe sections with loose joints, minimum diameter of 100 mm), respecting the slope of 0.2 - 0.5%. Plug the far ends with a cap and make the connection with each potential manhole watertight.
- Fill the infiltration trenches with clean gravel to a thickness of at least 0.05 m over the drains.
- Cover the gravel with geo-textile, or if not available, perforated plastic sheeting.
- Backfill all the trenches to the top with earth and compact it lightly.
- Plant grass on top after one or two weeks to limit erosion.



Key

- A. Longitudinal section
 B. Bird's view of the multiple trench system
 C. Cross section

1. Permeable soil
2. Clean gravel
3. Incoming pipe
4. Drain pipe
5. Geo-textile or perforated plastic sheeting
6. Compacted earth
7. Plug at the end of the drain pipe
8. Distribution box
9. Manhole (optional)
10. Water table
11. Union pipes with elbow

Input

- Tape measure, string lines and pegs
- Shovels, hoes, picks, miner's bars and wheelbarrow
- Reinforcement bar or ½" galvanised pipe and hammer
- PVC pipes, (min. diameter 100mm)
- Drainpipes (perforated or porous pipe or pipe sections with loose joints)
- 2 elbows for drain pipes
- 3 end caps for drain pipes
- Construction material for distribution box / manholes
- Geo-textile or plastic sheeting
- Grass
- Temporary fence material

*Measurements are indicated in m
 Figures not up to scale*

Remarks

- Dispersal systems using simple or multiple trenches with infiltration pipes are a good alternative to soak away pits:
 - for somewhat less permeable soils or where there are large quantities of effluent;
 - in the case of a high water table or where there are rocky layers near the surface.
- To estimate the dimensions of the trench, evaluate the infiltration capacity of the soil (T.B. 4.05) and allow for a possible increase in the amount of wastewater to be disposed of. As the infiltration rate of the soil might differ over the length of the infiltration trench, the rate should be verified at several locations along the projected trench.
- Enough space should be available to install infiltration trenches (e.g. in high-income countries, a minimum ground surface area of 30 m² is foreseen for about 500 l of wastewater per day). Be aware that the infiltration will only take place via the vertical walls of the infiltration trench, thus the bottom should not be included as an infiltration surface (due to an “impermeable” bacterial layer forming on the bottom).
- The bottom of the infiltration trenches should be at least 1.5 m (preferably 3.0 m if connected to a septic tank) above the highest possible water table (during the rainy season). The depth of the water table can be estimated by verifying its level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½” galvanized pipe in the ground, as deep as 1.5 m beneath the required trench depth. When pulled out, the rod or (the earth inside) the pipe should be dry. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level.
- The dispersal trenches should be at least 1.5 m apart from each other. The distribution box with inspection cover (T.B. 4.03) installed at the beginning of the drains is to ensure that the effluent flow is well divided over the different pipes. The small manholes installed at the end of the infiltration pipes could facilitate the unblocking of the drains if their end caps can be removed.
- The dispersal drain pipes should have their holes starting at least 0.5 m away from the distribution box.
- The geo-textile or perforated plastic sheeting over the gravel bed prevents the entry of soil, which could block the system and/or limit the infiltration, but still allows air to go in and gasses to get out of the trenches.
- Cut the grass regularly in order not to become a breeding and/or hiding ground for vectors.
- A grease trap (T.B. 4.04) should be installed in front of the infiltration trenches when the wastewater originates from a kitchen, showers, a sink or a washing area, in order to avoid clogging by oil and fat.

T.B. 4.08 Evapo-transpiration area

Evapo-transpiration is useful in hot arid areas where a soak away pit or infiltration trenches cannot be used because of “impermeable” soils (e.g. clay or rock). It combines evaporation of water from the soil and transpiration by the vegetation, after that the effluents have passed the necessary pre-treatment.

Principles

Evapo-transpiration is a complex phenomenon that varies with the latitude, the season and the period of the day. An acceptable approximation can be given by:

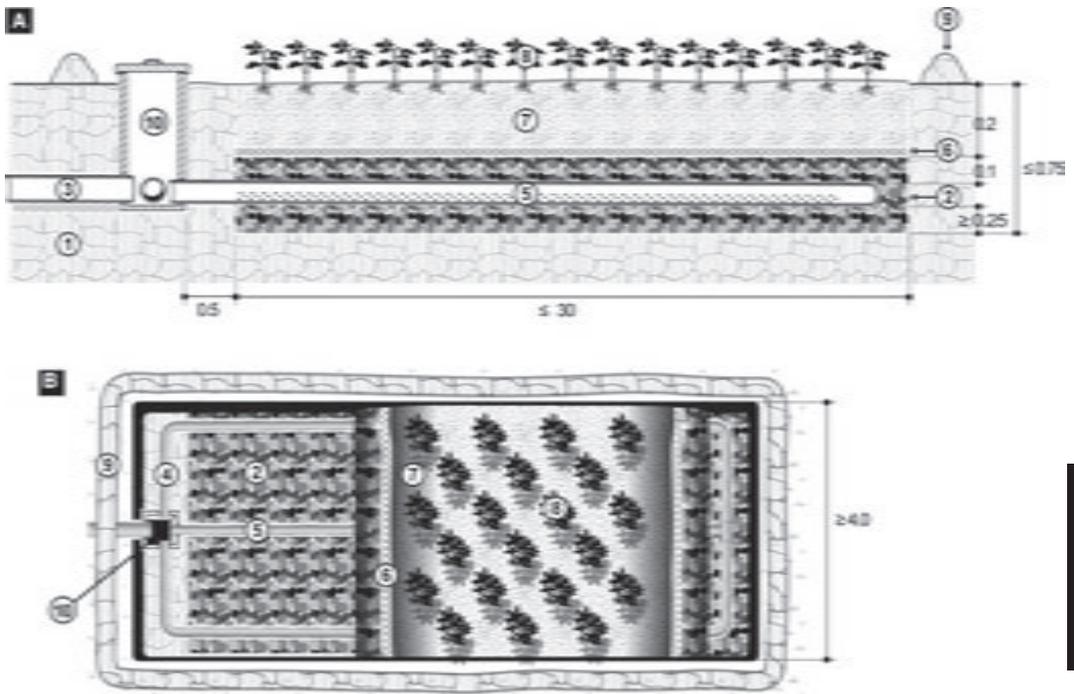
Evapo-transpiration rate (mm of water per day) = 0.8 x Evaporation rate of an open basin

The “ground” dimensions of an evapo-transpiration area may be calculated on this basis, in the absence of other data.

Effective area = volume of wastewater (m³/day)/evapo-transpiration rate (m/day)

Construction

- Choose a site as close as possible to the grease trap, but at least 6 m from dwellings, 7.5 m from trees or hedges and 3 m from property boundaries. The site should preferably be downhill and at least 30 m away from (ground)water sources.
- Determine the dimensions of the evapo-transpiration area according to the information above.
- Prepare the site for construction: remove all debris, lay out the area with string line, install a temporary fence and bring in the needed construction material and equipment.
- Dig the trenches (about 0.3 m wide and at least 0.3 m deep) for the incoming pipe (at least 1% slope) and the union pipes to form the trident pattern for the drains (at least 1.5 m apart from each other).
- Excavate the evapo-transpiration area with a 0.2% slope, at least 4 m wide, maximum 30 m long and about 0.25 m deeper than the end of the union pipe trenches (but not deeper than 0.75 m overall).
- Construct a distribution box at the end of the incoming pipe trench.
- Install the incoming pipe and the union pipes with elbows (min. diameter 100 mm) in the trenches, potentially on a layer of sand, and make the connections with the distribution box watertight.
- Install the dispersal drains (perforated PVC pipe with a minimum diameter of 100 mm) on a bed of clean uniform sized gravel (diameter of 20 – 50 mm), while respecting the foreseen slopes of about 0.2%. Make the connections with the union pipes watertight, and interconnect the far ends of the dispersal drains.
- Fill the evapo-transpiration area with a layer of clean uniform sized gravel, at least 0.1 m above the dispersal drains and cover it with geo-textile. If geo-textile isn't available, it can be replaced by a thin layer of fine gravel mixed with clean coarse sand to avoid that fine soil particles will get in between the uniform gravel and cause blockages. If needed, clean sand can also be added on top of this thin layer until 0.2 m underneath the ground surface.
- Cover the evapo-transpiration area with about 0.2 m water absorbing topsoil. In case the topsoil would not be very water absorbing by itself, it can be mixed with clean sand.
- Backfill the incoming trench with slightly compacted soil.
- Build an embankment around the complete evapo-transpiration zone to protect it from runoff water.
- Plant or sow over the whole area a quick-growing local grass that has a high water consumption.



Key

Input

A. Longitudinal section
 B. Bird's view (exploded views at certain places)

- | | |
|---|---|
| <ol style="list-style-type: none"> 1. Impermeable soil 2. Clean gravel 3. Incoming pipe 4. Union pipes 5. Drains interconnected with elbows and tee 6. Geo-textile (or coarse sand / gravel mixture) 7. Topsoil 8. Quick-growing grass 9. Runoff protection embankment 10. Distribution box | <ul style="list-style-type: none"> - Tape measure, string line and pegs - Shovels, hoes, picks, wheelbarrows - PVC pipes (min. diameter 100 mm) - Dispersal drains (perforated; min. diameter 100 mm) - 4 elbows and 1 tee for union and drain pipes - Gravel (diameter 20 – 50 mm) - Geo-textile or coarse sand and fine gravel mixture - Construction material for distribution box / manholes - Water absorbing soil (and possibly clean sand) - Quick-growing grass - Temporary fence material - Reinforcing bar or ½" galvanised pipe and hammer |
|---|---|

*Measurements are indicated in m
 Figures not up to scale*

Design calculation example

A dispensary in a hot, dry tropical zone generates 300 l of wastewater per day. The rocky soil will not allow underground dispersal. The evaporation rate is a very high 10 mm/day.

Evapo-transpiration rate = $0.8 \times 10 \text{ mm/day} = 8 \text{ mm/day}$ or $0.008 \text{ m of water/day}$

Effective area = $(0.3 \text{ m}^3/\text{day}) / (0.008 \text{ m/day}) = 37.5 \text{ m}^2$ (in practice about $4 \text{ m} \times 10 \text{ m}$ ground surface)

ATTENTION: values for evapo-transpiration of only 2 mm of water per day ($2 \text{ l/m}^2\text{-day}$) have been recorded in arid areas of the northern hemisphere.

Remarks

- The evapo-transpiration area is only suitable for hot, windy, arid or semi-arid climates and can only deal with very limited wastewater volumes.
- The evaporation rate (minimum, maximum and average) for a certain region might be found in specialized literature, universities or weather stations (e.g. airports).
- If the evaporation rate is not known, it may be roughly measured using an open (square) 1 m^2 basin filled with water that is placed outside on the ground (but not exposed to the rain). By measuring every day precisely the water height in the basin over several days, the average water evaporation can be calculated. Be aware that the longer the measuring period lasts, the more precise the average result will be. Know that 1 mm of water evaporated within the 1 m^2 basin represents 1 litre.
- Small manholes could replace the Tee and elbows at the end of the infiltration pipes, which could facilitate the potential unblocking of the drains. The distribution box and the potential manholes should have an inspection cover.
- The dispersal drain pipes should have their holes starting at least 0.5 m away from the distribution box.
- Choose a short-rooted grass that needs a lot of water for growth. Trees absorbing a lot of water (e.g. papaya) might break the pipes with their roots, thus they shouldn't be used for this purpose.
- Cut the grass regularly in order not to become a breeding and/or hiding ground for vectors.
- A grease trap (T.B. 4.04) should be installed in front of the evapo-transpiration area when the wastewater originates from a kitchen, showers, a sink or a washing area, in order to avoid clogging by oil and fat.



Collection and Disposal of Refuse

Narrative

Technical briefs

T.B. 5.01 Collective dustbins

T.B. 5.02 Refuse pit

T.B. 5.03 Controlled tip

Chapter 5



5.1 Why does refuse have to be managed correctly?

The accumulation of refuse (solid waste) creates a health risk, a nuisance as well as an environmental pollution problem. The health risks are essentially related to the proliferation of insect vectors and rodents:

- The breeding of flies that play a major role in the transmission of faeco-oral diseases;
- Mosquitoes of the *Aedes* genus (responsible for the transmission of dengue, yellow fever and other arboviruses) that lay eggs in water accumulated in empty tins, drums, tyres, etc.;
- Mosquitoes of the *Culex* genus (liable to transmit microfilariaes) which breed in stagnant water heavily loaded with organic matter;
- Rodents attracted by the refuse, which are directly or indirectly responsible for the transmission of various diseases such as plague, leptospirosis and salmonella, and whose presence attracts snakes.

Another health risk can be for human scavengers looking for useful material that can lead to injuries and all kinds of diseases (e.g. tetanus).

In addition to these health risks, poor management of the collection and disposal of refuse may involve the pollution of surface water and/or groundwater. Incorrectly discarded waste also increases the risk of fire and enables a rapid spread of it when started. Smoke emissions containing pathogens and hazardous by-products (carbon monoxide, sulphur dioxide, dioxin, furans and heavy metals) can occur when waste is burned in an open fire. Lastly, the aesthetic aspects (sight and smell) are far from negligible. These risks and nuisances are all the more serious at high population densities.

5.2 What is considered as refuse?

Refuse is all the solid material that is considered to be non-useful, thus people want to dispose of. Others might still find a purpose for this material and recycle it in its original or a different form, to be used for its original or a different purpose. Refuse can be domestic waste, or waste related to professional activities. Solid waste that is generated by patients and their visitors at health centres can also be considered as refuse. Medical waste however is specific and is dealt with in a separate chapter of these guidelines (Chapter 6).

The type and quantity of refuse produced by a community are extremely variable. The main factors affecting the composition of refuse are:

- The geographic region: e.g. often more plastic in Asia than in Africa;
- Socio-cultural: material levels and living standards may create great variations, as poor people in low-income countries have a tendency to recycle more;
- Seasonal variations: different kinds of food during different seasons;
- The importance and diversity of refuse-generating activities: e.g. workshops, markets;
- The packaging of food rations: mainly brought in by aid-agencies.

The density of refuse can be estimated to be between 100 to 200 kg/m³. The daily generated volume varies between 0.5 and 10 l/person. In general, it may be assumed that the daily volume of refuse will be small (on average more towards 0.5 l/person) when dealing with a population of rural origin and where the basic ration is under the form of dry foodstuffs (as is often the case during the initial phases of an emergency operation). But these quantities can rise quickly when aid-agencies start with the distribution of individually packaged food rations, which can't be reused / recycled. The amount of refuse generated in urban areas is often higher as well than in rural zones. The percentage of putrescible matter may range from 20 to 70%. These figures present orders of magnitude, and in practice the quantity and volume (or density) of refuse should be determined for each situation. Its composition is only really important when disposal is by means of incineration or composting, as it has an impact on these forms of waste treatment.

5.3 Where / When should refuse management be implemented and by Who?

Refuse can be generated at many different places such as domestic level, workshops, warehouses, slaughter areas, markets, food distribution points, aid-agency premises or health structures. It is obvious that collection and correct disposal of refuse always have to be done to avoid health risks as well as pollution problems, certainly in high population densities where the risks and nuisances are all the more serious. The refuse disposal management in rural areas can be done on a “household” level by the population, but for camps and collective buildings / centres (e.g. after a natural disaster) a collective approach might often be more appropriate, certainly in the early stages of an emergency. The long-term refuse disposal management for urban zones, also mainly a collective approach, falls out of the scope of these guidelines. The focus in this chapter will be mainly on emergencies.

The choice, the implementation and the maintenance of the refuse disposal method should be discussed and agreed upon with all the stakeholders (e.g. aid-agency, population, local authorities) in order to have the facilities installed, used and cleaned correctly (e.g. at public institutions such as markets, slaughterhouses and food distribution points; choice of the collective site for final disposal). Health promotion activities can help to achieve this.

5.4 How should domestic refuse be managed?

5.4.1 Planning and organization

For correct planning and organisation of refuse disposal, it is necessary to follow all the different steps described in chapter 1. Some specific points directly related to domestic refuse disposal, are gathered below.

If “**household” level management** is chosen, the strategy will mainly focus on promoting the system, informing the population how to make and to use a refuse pit (which can be shared by several households in camps for instance), and lending them tools and material for the construction of the pit and for the collection of the waste.

For a **collective management**, focus will go more towards finding correct spots to construct collective burial places or controlled tips and setting up temporary storage, general collection and transport systems. Staff will need to be trained to do correct operation (e.g. collection, transport and final disposal of waste) and maintenance (e.g. waste containers, collective burial places).

It will also be necessary to promote the collective refuse disposal system to the population, to inform them on the existence and the correct use of the facilities like the waste containers, and possibly to provide material for the domestic collection of the waste at their dwelling. The more users friendly the facilities are, the more they will be used. Correctly maintained facilities will also be needed to keep the population motivated to continue using them. For a more durable solution, the population themselves should perform the maintenance of the provided material, even the waste containers.

Segregation of different kinds of waste is interesting, but will be extremely difficult to achieve during an emergency situation. Most of the “waste” that still has a value (e.g. aluminium cans) will be recycled anyway.

5.4.2 Technical process

	Household level management	Collective management
Temporary Storage	Waste bin (at dwelling level)	100 l drum (max. 15 m away)
Collection	Household member	Team (2.5 pers/1000 inhabitants)
Transport	Manual	Cart / motorised vehicle
“Treatment” (incineration, composting)	Generally not recommended	Only if specialised equipment and personnel are available
Final Disposal	Domestic refuse pit	Burial trenches or controlled tip

Household refuse disposal management

■ Temporary storage, collection and transport

At dwelling level, people can use a simple recipient (e.g. bucket) to temporarily store their waste, but very often a family member will collect and transport the refuse directly to the final disposal place. There are no vehicles required because this place is located nearby the dwelling.

■ “Treatment”

On household level, incineration / burning of refuse is generally not recommended, as the food residues contain a lot of liquids. It means that a lot of fuel will be needed for their incineration, which is (very) costly. As wood is often used for “incineration” / burning in low-income countries (certainly in emergencies), it would lead to an even higher stress on the local environment. It may even be dangerous when it is done on a large scale, due to air pollution and the increased fire risk.

Composting is a biological decomposition of organic matter in the presence of air, as opposed to anaerobic decomposition that takes place in septic tanks for instance (and which is very smelly). Composting can only be considered if the population has already an extensive experience in this matter or if a complete project with appropriate material, intensive training and monitoring is set up. Be aware that composting doesn't always correspond to the habits and culture of the population. For these reasons is composting often not recommended in (acute) emergency situations.

■ Final disposal

The easiest way of final disposal is to throw the refuse in a pit (T.B. 5.02). The bottom of the pit should be at least 1.5 m above the highest possible water table (during the rainy season), because this reduces the chance of microbiological contamination of the groundwater virtually to nil in homogeneous soils. The needed depth for fissured soils is difficult to predict however. The pit needs to be covered with a lid every day. If a lid isn't available, the refuse should be covered with a layer of 0.10 m of compacted soil or 0.25 m of non-compacted soil, to avoid bad odours and vectors or other animals being attracted to it. But this will fill up the pit extremely fast. Fencing is necessary to avoid people falling in the pit, certainly at night. Chopped up organic waste could also be buried in very shallow trenches of little gardens to be used as nutrition supplements for the crops. This demands a daily management, which is most probably a too heavy burden, certainly in emergencies. Another alternative is to give the organic waste to “domestic” animals as food.

Collective refuse disposal management (within refugees / IDP camps)

■ Temporary storage (in refuse containers)

The objectives are to gather the refuse in order to facilitate the collection and to avoid its dispersion by the wind and animals. Half 200 l metal drums are generally used (T.B 5.01), but other recipients (e.g. plastic containers) can do also as long as they can't be blown over by the wind. However these containers must be solid and have a volume of at least 60 l and maximum 100 l. The bottom of the collective dustbins should be pierced so that they do not retain decomposition liquids (bad odour) and to avoid that they would be used for other purposes. The dustbins should be provided with covers and with handles for easy lifting. In the first instance, one container per ten to fifteen families may be provided, placed at a reasonable distance from the dwellings (preferably not less than 5 m and not more than 15 m away).

Certain structures need particular storage systems, either because of the specific nature of their refuse (e.g. specific workshops like garages), or because of the large volumes produced (e.g. market, slaughterhouse, various workshops). For public places, a team will be needed to remove the waste that has been dropped directly on the ground / floor.

■ Collection and transport

Collection should preferably be done daily to avoid the hatching of flies and odour problems. The collection of the contents of the waste containers, including incorrectly discarded waste, may be done with motorised vehicles (pickup, truck, tractor with trailer), but it may be more reliable logistically to use

handcarts or animal carts. Moreover, it is difficult, specially in emergency situations, to commit a motorised vehicle exclusively to this task. The bottom of the carts can be perforated with small holes (about 10 mm diameter) to allow sand to fall out of the waste in order to diminish its weight. Whatever vehicle is used, they should be equipped with simple tools like brooms, shovels and disinfection equipment to clean the storage facilities on a regular basis.

Circuits must be established and teams (e.g. 2.5 persons/1000 inhabitants) formed. A circuit must be allocated to each team. After its introduction, the collection system should be supervised and evaluated periodically if the circuit and the resources are appropriate and sufficient.

These two steps of storage and collection require the co-operation of the population, which should also be involved regularly (once or twice per month) in a general clean up of the camp, including the market, the dwellings and their surroundings.

■ “Treatment”

Incineration can only be an appropriate treatment method when real (domestic) refuse incineration plants with qualified personnel are available and operational (e.g. Eastern countries). As the distance in between the camp / setting and the incinerator will most probably be long, trucks will be needed and thus the costs will rise significantly. The incineration itself might be rather expensive as well. So it will be only under specific circumstances that incineration can be considered as an option (e.g. lack of space in the setting, legislation). “Incineration” or burning refuse in or even outside the camp / setting itself must be avoided as it increases the health risks due to air pollution and fire hazard.

Composting at communal level is an interesting but difficult technique to manage, certainly in (acute) emergencies, because the waste should be properly segregated before by the population. It needs special care and your technical referent must be involved because composting may cause health risks and serious odour nuisances if not implemented correctly.

■ Final disposal

Dumping of waste (in or even outside a camp / setting) should be avoided at all times as it attracts vectors and scavengers (animals and humans), thus forming a serious direct health risk. There is also the risk of environmental pollution (e.g. pollution of surface and/or groundwater) and fire.

An efficient and rather cheap way of final disposal is burial. Still, special attention should go to the potential risk of environmental pollution and thus indirect health hazards when refuse is buried. The construction of the pits / trenches should follow the same rules as for building latrines, as the risk of polluting the water table is similar.

Burial can be done on a collective level in trenches, which can be constructed, operated and maintained with (only) manual means, as long as the quantities of refuse stay reasonable. For very big quantities of refuse, it might be necessary to use controlled tipping (T.B. 5.03). This procedure requires sufficient space at a distance at least 800 m away from the dwellings and an access to mechanical equipment (e.g. trucks, bulldozers). The refuse must be covered daily to avoid vectors (e.g. insects, rodents) or other animals (e.g. dogs, foxes, seagulls) to be attracted. Access to the site should be restricted by a fence. If a good drainage is not ensured, there is a great risk of the trenches / controlled tip turning quickly into sickening swampy areas.

■ Protective clothing for the staff

All staff involved in the collective disposal of refuse will need the following protective clothing:

- Overall,
- (Heavy-duty) boots,
- Heavy-duty gloves,
- Mask.

It is recommended to foresee a washing place for the staff, where there is at least water and soap available.

5.5 Further reading

S. Cairncross, R. Feachem

Environmental Health Engineering in the Tropics
Willey, 1993

J. Davis, R. Lambert

Engineering in Emergencies: a Practical Guide for Relief Workers
Intermediate Technology, RedR, 2002

P. Harvey, S. Baghri, B. Reed

Emergency Sanitation
Water, Engineering & Development Centre (WEDC), 2002

T.B. 5.01 Collective dustbins

The dustbins may be used along paths and roads in a refugee camp, public places like a market or school, or on the compound of a health structure. The objectives are to gather the refuse in order to facilitate the collection and to avoid its dispersion by the wind and animals.

Construction

- Cut a 200 l oil drum in two.
- Make sure that the sharp edges are worked in such a way that they can't injure the operator.
- Pierce about 20 holes in the bottom to let decomposition liquids (leachates) drain out and to avoid theft (people using the drum for other purposes).
- Fix two handles on the sides of the drum for carrying.
- Prepare a cover with a handle for opening and make sure there aren't any sharp edges.
- Fix the cover on the open end of the drum with a heavy duty hinge or an alternative (e.g. metallic wire).
- Paint the inside and outside of the dustbin with anti-corrosion paint.
- Paint the outside in a bright and attractive colour to make it clearly visible.
- Make a support. In the first stage of an emergency a metal or wooden support can do. In a later stage, the support can be made with bricks.
- Dig a hole where the dustbin will be placed, preferably 0.5 m deep, at least with the same diameter as the dustbin, and fill it with stones or gravel to drain the leachates.
- Place the dustbin with its support on the leachates drainage hole.

Remarks

- Plastic drums / bins can be an alternative solution, but they have to be solid. They have to have a volume of at least 60 l, but not more than 100 l to ease handling. These plastic waste bins should be provided with a lid, handles and a pierced bottom to drain the leachates (and to avoid non-appropriate use). Due to their light weight, a good support will be needed to avoid that they will be blown over or even away by the wind.
- Attach the cover in such a way that it falls shut every time it is dropped. This is the only way to be sure that the dustbin is always covered.
- Allow one dustbin for every 10 - 15 shelters / houses, and others along roads and in public places (schools, markets).
- Organize daily refuse collection and disposal.
- Organize regular cleaning and disinfection (0.1% chlorine solution, T.B. 2.20) of the dustbins and drainage holes. Rinse the bins thoroughly with clean water after disinfection.
- Collective dustbins that are in poor shape or heavily corroded should be replaced and repaired if still possible. The repaired dustbins can join the reserve stock that should be kept at all times.



Key

1. Cover
2. Handles
3. Heavy duty hinge (e.g. strong rope, piece of tire)
4. ½ (metal) 200 l drum
5. Pierced bottom
6. Support
7. Hole with stones or gravel (drainage)
8. Hammered edges

Input

- 1 drum, 200 l
- 1 cold chisel / hammer or metal saw
- Wire, nuts and bolts, or pop rivets for fixing handles and hinges
- 1 hinge (or a piece of rubber / leather / rope) to attach the cover
- Wood / metal for the support or bricks / stones, cement, sand and masonry tools
- 1 shovel, 1 hoe, 1 pick axe
- Anti-corrosion paint, colour paint
- Brushes
- Stones or gravel for leachates drainage

T.B. 5.02 Refuse pit

In an emergency situation, an appropriate way to dispose of household refuse (not medical waste) is burial in collective or family refuse pits, certainly if there are not enough transport means and/or land available for controlled tipping. The high liquid content of this type of refuse does not allow the waste to be burned with simple means; apart from using a lot of fuel, its incomplete combustion could even be a health risk factor. This treatment method also increases the risk of fire drastically.

Construction and use

- Respect the minimum distances to avoid the risk of contaminating water points.
 - The distance from water points must be > 15 m if the pit serves fewer than 10 families, > 30 m in all other cases.
 - The distance from dwellings must be > 10 m if the pit serves fewer than 10 families, > 30 m in all other cases.
- Make a fence around the area foreseen for the hole in order to avoid accidents and to prevent the entry of scavengers (human or animal).
- Dig a circular hole, leaving the soil to one side (to be used for the daily covering of refuse). For security reasons, the pit should not be deeper than 2 m, and the walls have to be made conical in order to reduce the risk of collapse, or reinforced with removable struts during the excavation.
- The bottom of the pit should be at least 1.5 m above the highest possible water table. The depth of the water table can be estimated by verifying its level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe into the ground, as deep as 1.5 m beneath the required pit depth. When pulled out, the rod or (the earth inside) the pipe should be dry. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level.
- Dig a drainage ditch around the pit to avoid it would flood. The ditch can be connected to the big drainage canals of the site if existing.
- Dispose of the refuse in the pit, covering it immediately.
- Backfill the hole completely with compacted soil when the refuse level is 0.5 m underneath the ground surface. A metal grid can be put on top of the refuse before the final backfilling takes place. Coming across the grid during future excavations will indicate that a pit has already existed on the same spot. It is also possible to plant on the old refuse pits fast growing vegetation (e.g. eucalyptus), which can be used as firewood afterwards. If there is no other available solution remaining, it should be safe after at least 6 months to dig at the same spot again (if no dangerous wastes have been thrown in).

Key

Input

- A. Cross section of refuse pit
- B. Minimum safety distances

- | | |
|-----------------------------|---|
| 1. Pit | - Pick axe, miner's bar, shovel and hoe |
| 2. Refuse, day 1 | - Buckets (to lift out the earth) |
| 3. (Compacted) earth, day 1 | - Reinforcing bar or ½" galvanised pipe and hammer |
| 4. Refuse, day 2 | - Stakes and fencing material |
| 5. (Compacted) earth, day 2 | - 2 people for 1 day (depending on the size of the pit) |
| 6. Fence | |
| 7. Excavated earth | |
| 8. Water table | |
| 9. Drainage ditch | |
| 10. Dwellings | |
| 11. Refuse pit | |
| 12. Latrine | |
| 13. Well | |

Remarks

- The refuse pit can also be used for rural waste management in small villages within stabilized situations.
- The pit should be circular because it will be more resistant against collapse due to its natural arching effect. The less stable the soil, the more the walls of the pit should be conical. If the soil is too unstable, it may be useful to support the pit walls (e.g. with planks, bamboo).
- Only throw household refuse in the pit. The chance of microbiological contamination of the groundwater is very limited in homogeneous soils if the bottom of the pit is more than 1.5 m above the aquifer.
- Do not throw in hazardous waste (e.g. old engine oil or even oil filters) because this could lead to a long lasting chemical pollution of the aquifer, even if the bottom of the pit is more than 1.5 m above.
- Although (potentially contaminated) medical waste can be buried, it has to be done in a completely controlled manner with specifications beyond this simple refuse pit; e.g. specially designed pits (see chapter 6), away from the population and integrated within a fenced waste zone or controlled landfill.
- It is potentially hazardous for people's health and the environment to burn household refuse in an open fire (e.g. smoke, risk of fire), so a collective or family waste pit should not be used for that purpose. The use of volume reducers and small incinerators (as described in T.B. 6.05 and 6.06) should be exclusively reserved for some medical wastes (mainly "soft" waste).
- It is essential that the refuse is covered, preferably with a lid, immediately after disposal to avoid attracting flies and rodents, to limit the risk of refuse being blown away and to reduce the nuisances (e.g. bad odour, visual). In case a lid isn't available, it can also be covered with earth (and possibly wood ashes), but be aware that the pit will fill up rapidly (each layer should be 0.1 m thick if compacted or 0.25 m if non-compacted).
- In case a new pit is being dug at the same spot at least 6 months after the old one has been closed, be aware that plastics and potential glass will still be "intact" and the latter might cause injuries.
- As the population has to do its own waste management with this facility, a good health promotion campaign and some training for proper use and maintenance might have to be organized for them.

T.B. 5.03 **Controlled tip**

This technique is used to eliminate community's wastes. Its feasibility is essentially dependent on the land surface available and/or the availability of collection and transport equipment like animal carts or lorries. The high liquid content of this type of refuse does not allow the waste to be burned with simple means; apart from using a lot of fuel, its incomplete combustion could even be a health risk factor. This treatment method also increases the risk of fire drastically.

Construction

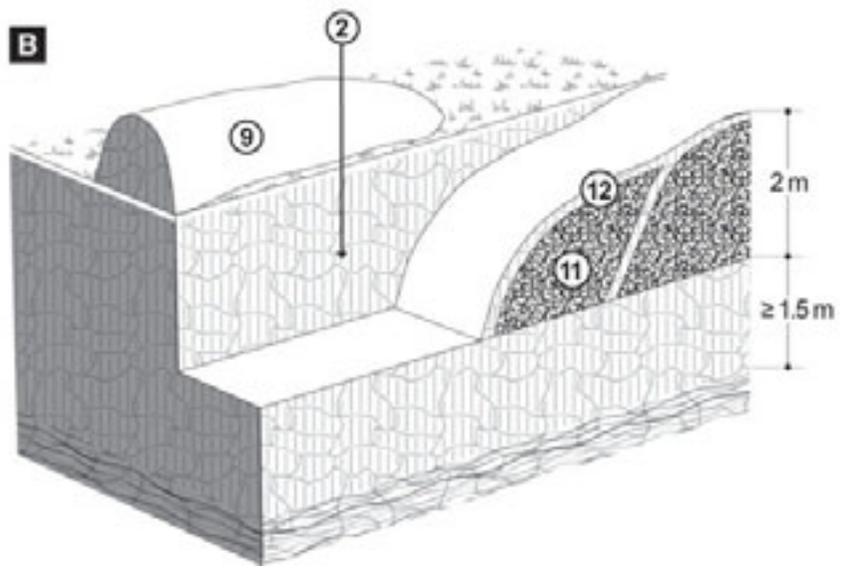
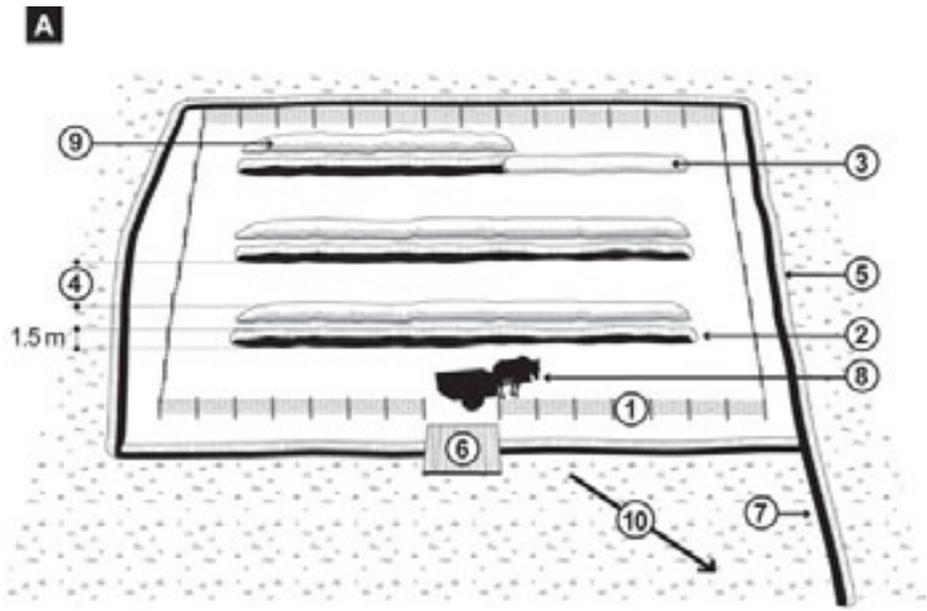
- Calculate the length of trenches needed using the following rule of thumb:

**for a width of 1.5 m at a depth of 2 m,
dig at least 1 linear m of trench per 200 people per week**

- Choose a flat area at least 800 m away from the dwellings and the living areas should not be downwind from the tip.
- Take also into account the distances from water resources, which should never be less than 50 m away and which should be uphill from the tip. The bottom of the trenches should be at least 1.5 m above the highest possible water table, this if the soil is homogeneous. This is to avoid that the leachates (liquids dripping out of the waste) would cause a microbiological contamination of the aquifer. The depth of the water table can be estimated by verifying its level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe into the ground, as deep as 1.5 m beneath the required trench depth. When pulled out, the rod or (the earth inside) the pipe should be dry. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level. In case the water table is too high, a different spot should be selected.
- Surround the tip with a fence to avoid accidents and to prevent the entry of scavengers (human or animal).
- Prepare the site for construction: remove all debris, lay out the area and bring in the needed construction material.
- Dig the trenches with conical walls, and its bottom should preferably be covered with clay, special plastic lining or even better a combination of both. But it's very doubtful that the material and certainly the time will be available in emergencies to perform these environmental protection works.
- Dig a surface water drainage ditch around the whole area to avoid runoff water going through. The lowest corner of this ditch should lead to an infiltration facility, which is foreseen with an overflow towards the big drainage canal to evacuate water that doesn't infiltrate during heavy rainfall.

Operation

- Collect the refuse and take it to the tip.
- Dump the refuse at one end of the trench and cover it immediately with at least 0.1 m compacted or 0.25 m of non-compacted earth. The following load should be dumped next to the first, and so on until the trench is full.



Key	Input
A. Controlled tip	
B. Detail of trench in use	- Plenty of land
1. Fence	<i>Construction</i>
2. Trench (part) waiting for use	- Reinforcing bar or ½" galvanised pipe, hammer
3. Trench part already full and covered	- Mechanical shovel or numerous workers with digging equipment (shovels, hoes, picks)
4. Alley (wide enough for the passage of the refuse collection vehicle)	- Poles / tree trunks or concrete slab to build the bridge crossing the drainage ditch
5. Drainage ditch	- Stakes and fencing material
6. Bridge (crossing point of ditch)	
7. Lowest corner (towards infiltration facility with overflow)	<i>Operation</i>
8. Cart / lorry bringing refuse	- Lorry or cart for transporting refuse
9. Excavated earth used progressively for covering	- Trained personnel, permanently at the tip
10. Runoff direction	- Shovels for covering refuse
11. Refuse	- Overall, heavy duty boots and gloves for staff
12. Layer of backfilled earth	- Brooms and 0.05% chlorine solution for daily cleaning of the cart or lorry
	- Washing facilities with water and soap

Remarks

- This technique needs a lot of land and (rather) sophisticated equipment for its implementation, which can entail heavy costs.
- The fence and guards are essential to avoid scavenging and accidents at the tip.
- The staff should be trained for their task and should wear protective clothes like an overall, a mask, (heavy-duty) boots and heavy-duty gloves. Washing facilities (at least water and soap) with the related wastewater structures should be available at the site.
- It is strongly advised to vaccinate all the staff coming potentially in contact with waste against Hepatitis B and Tetanus.
- The compulsory distance from dwellings demands the use of a lorry or (animal) carts. The bottom of the carts can be perforated (small holes of 10 mm diameter) to allow sand to fall out of the waste in order to diminish its weight. The transport means should be disinfected daily with a 0.05% chlorine solution and then rinsed thoroughly with clean water.
- If there is no other solution available, the trenches that have been covered for at least 6 months can be excavated again to be reused as a controlled tip. Be aware however that plastics and potential glass will still be "intact" and the latter might cause injuries. When hazardous wastes have been disposed of in the trenches, they should not be reopened.

Medical Waste Management

Narrative

Technical briefs

- T.B. 6.01 Sharps containers
- T.B. 6.02 Sharps pit
- T.B. 6.03 Safety box reducer
- T.B. 6.04 Mass vaccination campaign waste
(temporary safety box reducer)
- T.B. 6.05 Temporary volume reducer
- T.B. 6.06 Permanent batch incinerator
- T.B. 6.07 Residues (ash) pit
- T.B. 6.08 Organic waste pit ("Placenta" pit)
- T.B. 6.09 Waste zone
- T.B. 6.10 Protective clothing and equipment

Chapter 6



6.1 Why is medical waste management important?

Despite all existing hygiene precautions, nosocomial infections affect at least 5 to 15% of the patients entering health structures in high-income countries. The problem of nosocomial infections is most probably higher in low-income countries. In India, the nosocomial infection rate is estimated around 30%. The main reasons of those infections are insufficient hand washing, the use of non-sterile invasive devices, insufficient general hygiene and bad medical practices, but also to some extent incorrect medical waste management. Similarly to excreta, wastewater and refuse, improper disposal of medical waste can cause environmental pollution, together with serious smell and visual nuisance problems, and it also leads to health risks. Typical health risks related to improper medical waste management are:

- Direct contact with the waste, potentially resulting in its pathogens entering the human body:
 - Through a puncture, abrasion or cut in the skin (e.g. medical staff recapping used hypodermic needles leading to needle stick injuries; unaware and unprotected non-medical staff handling waste, including sharps; children playing with discarded used needles; patients being injected with recycled single use needles, as is the case in some low-income countries).
 - Through the mucous membranes (e.g. ocular contact).
 - By ingestion (through hands / mouth contact).
 - By inhalation.
- Air pollution:
 - Hazardous smoke emissions occur when medical waste is burned at low temperatures in a poorly designed incinerator or when the incineration is not properly conducted (e.g. when the incinerator is not preheated, an open fire in a pit). These emissions contain thermo-resistant pathogens and toxic by-products like carbon monoxide, sulphur dioxide, dioxins, furans, heavy metals, or other chemical agents when for instance expired drugs are burned.
- Pollution of water resources and the soil:
 - Untreated medical waste contaminating the soil and ground / surface water (used for drinking) with pathogens (e.g. faecal coliforms, hepatitis A, polio and tetanus) or chemical substances.
- Increased presence of vectors:
 - Proliferation of vectors (e.g. flies, mosquitoes, rodents) in discarded medical waste.

The variety of health risks suggests that not only the medical and non-medical staff of health structures are at risk, but also the patients and their visitors. Other people at risk are the personnel of possible external support services (e.g. laundry, waste management), the population living in the neighbourhood where medical waste is handled incorrectly, and specially human scavengers recuperating medical waste. Since HIV/AIDS has appeared, more attention has been given to medical waste management with the formulation of the universal and standard precautions.

6.2 What is considered as medical waste?

It concerns the characteristic waste generated during medical activities (within health structures). To have a pragmatic and comprehensible medical waste management system for low-income countries, it is recommended to classify the medical waste according to “common disposal properties”:

- Sharps: objects that can be responsible for perforations or cuts of the skin (e.g. needles, scalpels, ampoules, broken glass, AD-syringes).
- “Soft” waste: includes dressings (wet or dry), packaging, paper, cardboard, plastic, syringes without needle.
- Organic waste: placentas, aborted foetus, amputated limbs, organs, body fluids.
- Hazardous waste: a clear distinction should be made in between *recurrently generated hazardous waste* and *inappropriate / expired hazardous products*. The former, generated on a daily, weekly or two-weekly basis, should be dealt with immediately, whereas the inappropriate / expired hazardous waste should be taken care of in special elimination campaigns (e.g. once every six months). The latter falls outside the scope of these guidelines (section 6.5. Further reading).

However, both kinds of hazardous waste categories are to be found in the following subcategories:

- Laboratory waste: diagnostic test kits and chemical reagents.
- Biological hazardous waste: Tuberculosis sputum; urine, stool and body fluid (e.g. blood) samples from potentially infected patients; cultures of bacteria; all mostly coming from the laboratory.
- Pharmaceutical waste: opened but unused drugs, cold chain damaged vaccines, expired and/or unwanted drugs.
- Expired disinfectant solutions: all solutions that have been prepared since a certain period (e.g. 0.05% chlorine solution after 1 day, 1% chlorine solution after about a week).
- X-ray related waste: slightly radioactive waste, expired film and mainly the chemicals to develop the photos.
- Insecticides: leftovers of prepared insecticides used in vector control activities within or outside the health structure, expired or inappropriate products.
- Specific hazardous waste: groups a lot of products that can be common as well as rather particular to certain medical activities within a health structure. Some examples of specific hazardous waste are:
 - Material used to prepare and administer cytotoxic drugs (e.g. syringe, needle, gown, respirator).
 - Waste with heavy metal content (e.g. batteries, broken appliances containing mercury such as thermometers and blood pressure gauges).
 - Pressurised containers (although mainly recycled).
 - Waste from activities related to the health structure (e.g. engine oil of the ambulances, generators, motor pump).

Medical waste is part of health care waste, which also includes excreta, wastewater and administrative waste. Waste discarded by the patients and visitors is actually refuse (Chapter 5), but when generated in small quantities and well segregated by them, it can be integrated within the medical waste management. So can food packaging and plastic beverage bottles be considered as soft waste. Food residues, also from the kitchen, can be part of the organic waste. Food residues from patients having very infectious diseases like cholera and viral haemorrhagic fevers should not leave the health structure and should therefore always be considered and discarded as organic waste. Small amounts of vegetation waste (e.g. dead tree leaves) can be considered as organic waste, but for bigger quantities it is best to handle it as refuse (Chapter 5).

6.3 Where / When should medical waste management be implemented and by Who?

Correct medical waste management should be implemented and promoted in all health structures, from the smallest health post to the biggest hospital, going over nutritional feeding centres, isolation centres (e.g. cholera, viral haemorrhagic fevers) and medical laboratories. Furthermore, this should be done in all situations, from the acute phase of an emergency until stabilized situations (with the management system adapted to the actual stage of the intervention).

The hygiene committee of the health structure, consisting of key medical and non-medical staff, potentially representatives of the local and health authorities, the neighbourhood and the aid-agency should play a central role in medical waste management.

The possible treatment and final disposal should preferably be done on the site of the health centre itself, in a well-defined area, the waste zone (T.B. 6.09). This principle has the following advantages:

- The potential treatment and final disposal of the waste can be done by clearly defined, trustworthy and trained persons.
- The medical waste remains within the health structure, thus there isn't a risk of being misused externally.

The segregation of the medical waste should be done by the medical staff, where the collection should be taken care of by the cleaners, or ideally by the one or two waste managers. The latter are responsible for and specialised in the collection, potential temporary storage, possible treatment and final disposal of the waste. They also take care of the waste zone in general. It is important however that all the staff (medical and non-medical) receive adequate training, and use the necessary working gear and equipment (T.B. 6.10).

In addition, patients, attendants and visitors should also be informed where to store the waste they generate. Information campaigns towards the population living nearby a place where medical waste is handled and towards potential human scavengers should be foreseen.

6.4 How does medical waste have to be managed?

6.4.1 Planning and organisation

Health structures are responsible for ensuring that their medical waste is rendered harmless to all people potentially at risk. Therefore, good medical waste management should result in waste being:

- Non contaminated
- And/or inaccessible to people and vectors.

For correct planning and organisation of medical waste management, it is necessary to follow the different steps described in chapter 1. Some specific points directly related to medical waste management are gathered below.

For acute emergencies, the essential requirements (T.B. 1.08) regarding medical waste can often be applied immediately after an initial assessment. For chronic emergencies and stabilized situations however, an additional in-depth assessment should be conducted in order to have the essential requirements integrated in a context adapted manner. Special methodologies (section 6.5 Further reading) exist to help in the in-depth assessment.

An important issue in the planning phase during chronic emergencies and stabilized situations is that the strategy is defined in collaboration with the hygiene committee, and if possible formalized in a memory of understanding.

Providing only technical solutions (based on the described general recommendations) is not sufficient to implement a correct medical waste management system. They must be completed by general and specific technical trainings directed towards medical and non-medical staff, and health promotion towards patients. The management system must combine safety features with easy to use measures, adapted to the needs, habits, culture and other constraints of the users. Obviously, the national legislation regarding medical waste, if existing, should be respected.

In order to be able to implement as soon as possible the technical training of all the staff, it is often worthwhile to start with a temporary waste zone based on emergency facilities like a temporary safety box reducer (T.B. 6.04) and a temporary volume reducer (T.B. 6.05), even in a chronic emergency or stabilized situation.

For hospitals up to 100 beds, the general recommendations are normally sufficient. It might be necessary for infrastructures with more than 100 beds to double or triple the facilities (e.g. two incinerators, double the number of organic waste pits, of which two are operational at the same moment in order not to be filled up too quickly and allow the decomposition of the waste). For 300 beds and more, other solutions for the medical waste are probably required (e.g. factory made incinerators).

It is recommended to vaccinate the medical and non-medical staff who are potentially exposed to medical waste, at least against Hepatitis B and Tetanus.

Medical Waste			
Segregation ▼	Sharps ▼	Soft waste ▼	Organic waste ▼
Temporary storage ▼	Yes ▼	Yes ▼	No ▼
Treatment (burning / incineration) ▼	No ▼	Yes ▼	No ▼
Final disposal	Sharps pit	Refuse pit	Organic pit

6.4.2 Technical process

The entire technical process should preferably be done on the compound of the health structure to avoid as much as possible accidents (e.g. needle stick injuries). If any waste has to leave the compound anyway, extra security measurements should be taken, which might require support from your technical referent. To achieve a correct medical waste management, different “technical” steps for sharps, “soft” and organic waste have to be accomplished, as presented in the table above. Hazardous waste demands specific attention for their entire technical process, and advice should be asked at your technical referent.

Segregation

The segregation process and corresponding management has to be as simple as possible. Therefore, no difference is made between contaminated and non-contaminated waste. The segregation of the medical waste in the different categories as described before should be done by the medical staff (e.g. doctors, nurses, laboratory technicians, pharmacists) at the place and time that the waste is generated. Attempting to segregate the medical waste at any other place or time introduces additional and non-acceptable risks.

The kind of recipients to use for the segregation depends on the category of waste generated:

- Sharps: modified drugs container, Reusable Sharps Container, commercial disposable sharps container.
- Soft waste: plastic buckets with a capacity of 20 to 60 l, all of the same colour, with a well fitting lid.
- Organic waste: plastic buckets with a well fitting lid, a capacity of 15 – 20 l for deliveries and 40 – 60 l for the operating theatre. All should have the same colour, but different than those for the soft waste.

Collection and temporary storage

The frequency of medical waste collection depends on the type of waste category. Sharps should be collected at regular intervals or at the latest when the disposable (single use) container (T.B. 6.01) is ¾ full, “soft” waste on a daily basis and organic waste as soon as possible after the intervention. Sharps and “soft” waste can be stored temporarily in safe containers within the waste zone (although not recommended) whilst organic waste has to be disposed of immediately.

Treatment and/or final disposal

If possible, every health structure should have a waste zone (T.B. 6.09), where the waste can be treated and/or disposed of. This zone will be composed of several facilities:

- A temporary storage area for the soft waste,
- An incinerator (T.B. 6.06) or temporary volume reducer (T.B. 6.05),
- Different waste pits: sharps pit (T.B. 6.02), equipped or not with a safety box reducer (T.B. 6.03), residues (ash) pits (T.B. 6.07), organic waste pits (T.B. 6.08),
- A place to wash the waste recipients, including appropriate wastewater facilities (Chapter 4).

The size of the waste zone depends on the amount of waste that is generated, thus on the size of the health structure itself and on the number of patients that are treated each day. The quantity of medical waste generated daily in low-income countries varies normally between 0.3 to 1.5 kg/bed (or 2 to 3 l/bed). The actual quantity of waste generated per category must be determined by each health structure itself in order to set up a correct medical waste management system. It is important to foresee sufficient space for the waste zone, as new pits will have to be dug once the old ones are nearly full. However, the different treatment / disposal facilities must be kept rather close together, to avoid spreading of the contamination over a large area and to provide an “ergonomic” and convenient working environment for the waste manager.

Few medical waste treatment methods are appropriate, affordable or available in the field. Burning in a volume reducer or preferably incineration in a double combustion incinerator often remain the most suitable treatment methods for soft waste in low-income countries. An exception may be urban situations where the space to build an incinerator is limited or where the smoke would cause a nuisance to the neighbours. Another exception could be very small health structures (in rural areas) where the production of medical waste is limited and the available space on the compound large enough for land filling.

Burning and incineration with limited means are too complicated (thus potentially dangerous) and too energy (fuel) consuming for sharps and most organic waste, thus the treatment is by-passed for these categories. Sharps and organic waste are disposed of directly in their respective pits.

Food residues can be disposed off in the organic waste pit if they are produced in small quantities (less than 10 l/day), if not the pit will fill up too fast. For higher quantities, burial at an “official” landfill should strongly be considered. Composting could also be an alternative but to do it correctly, it demands motivation and specific knowledge, which falls out of the scope of these guidelines.

Recurrently generated hazardous waste has to be managed on a case-by-case basis. Small amounts of chemical liquids (e.g. lab reagents and X-ray developing products) can be diluted with plenty of clean water before being discarded via a sink connected to a closed sewer system or a river with a substantial flow. Bio-hazardous waste like tuberculosis sputum, bacteria cultures or blood samples should be incinerated whilst adding sufficient combustibles, and preferably be autoclaved before when coming from the laboratory. Materials being used to administer cytotoxic drugs (not including sharps) should be collected separately and be incinerated in a double combustion incinerator with additional fuel to ensure a high combustion temperature. Glass bottles containing (bio-)hazardous samples or opened vials still containing vaccines have to be disposed of in a completely lined sharps pit or have to be encapsulated. Urine and stools can be disposed of in pit latrines, as long as the safety distances with water points are respected (Chapter 3). Disinfectant solutions can be “recycled” for cleaning the floors of non-critical areas (e.g. NOT for an operating theatre). Prepared but leftover insecticides that have been used for spraying health structures indoors can be utilised to treat the latrines. For the correct management of specific hazardous waste, ask advice to your technical referent.

Inappropriate / expired hazardous products have to be eliminated according to the national legislation (if existing) or during specially organised (six monthly) campaigns, based on the feedback of your technical referent on the hazardous waste list that you have send (section 6.5 Further reading).

6.5 Further reading

Médecins Sans Frontières

Medical Waste Management in Low-Income Countries CD-ROM

Contains following manuals:

- Medical Waste Management in Low-income Countries, 2010
- Manufacturing Sheets for Waste Zone Facilities in Emergencies, 2010 (2nd edition)
- Safety Box Reducer: Construction & Operation Manual, 2010 (2nd edition)
- Incineration in Health Structures of Low-Income Countries: Construction & Operation of the De Montfort Incinerator, 2010 (2nd edition)
- Waste Zone Operators Manual, 2010 (2nd edition)
- Hazardous Waste Management within Health Structures of Low-income Countries, 2010 (2nd edition)

Médecins Sans Frontières, 2010

Médecins Sans Frontières

Post exposure prophylaxis (PEP). A guideline in case of accidental exposure to blood.

Médecins Sans Frontières, internal document, January 2000.

A. Prüss, W.K. Townsend

Management of waste from health-care activities: Teacher's Guide

World Health Organisation, 1998

A. Prüss, E. Giroult, P. Rushbrook

Safe management of waste from health-care activities

World Health Organisation, 1999

WHO

Guideline for safe disposal of unwanted pharmaceuticals in and after emergencies

World Health Organisation, 1999.

T.B. 6.01 Sharps containers

Sharps are considered to be part of the most dangerous medical wastes. They are at the basis of most accidents that happen to the medical staff in health structures. In addition, other groups of people within health structures (e.g. patients, non-medical staff like the cleaners) are potentially also at risk of sharps injuries. It is therefore of utmost importance that sharp wastes are immediately discarded in correct sharps containers, when and where they are generated.

Principle

Commercial disposable (single use) sharps containers are easily available in high-income countries, but often unaffordable for low-income countries, certainly when the aid-agency pulls out. Thus, it is often necessary to find cheaper, but as safe alternatives. To have good and safe sharps containers, they must:

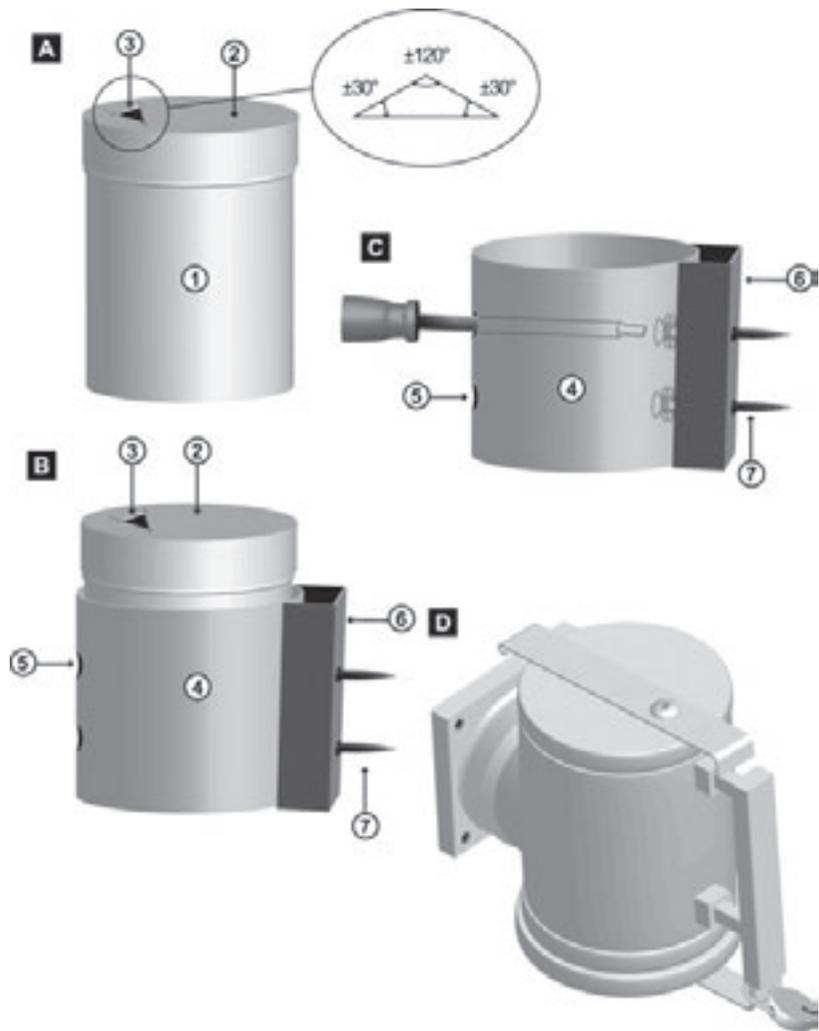
- be puncture resistant.
- be made out of solid material that doesn't have a big recycling value.
- be leak proof.
- have a sufficient volume (at least 0.5 l, preferably 1 l).
- be affordable for low-income countries.
- be easily available.
- have a facility that allows the separation of a needle from a syringe with a one-hand movement.
- be able to receive other sharps than needles as well (e.g. blades, scalpels, glass).
- be fixed in every treatment room (e.g. on the wall nearby the place where the injections are given) or on a tray / trolley for treatment at the patients' bed within the wards.

Based on these specifications, glass / plastic infusion and beverage bottles are prohibited and it is strongly recommended not to use soft drinks / beer cans as sharps containers either. Correct alternatives are modified empty generic drugs containers, preferably the sturdy plastic models, although that metallic ones can also be used.

Procedure

Transformation of a plastic generic drugs pot into a disposable (single use) sharps container:

- Choose an empty drugs container that is sturdy, has enough storage capacity and a well fitting lid. It should also be well rinsed with water and dried afterwards.
- Make with a cutter knife a triangular hole in the top of the lid nearby its edge (see figure). The hole size depends on the sharps waste that has to be disposed of. Make sure that at least one corner of the triangle has a sharp angle to facilitate the one-hand removal of the needle from a Luer syringe.
- Put some glue for plastics on the circular inner edge of the lid and remount it on the container. The container can only be used once the glue has dried and the lid is securely fastened.
- Provide a holder system for the sharps container to be fixed to a wall, tray or trolley; e.g. Velcro straps or a PVC pipe (connector) with strong elastic bands. It's important that the sharps container can be removed from the holder for final disposal, but it should stay immobile during the segregation of the sharps (e.g. needle being separated from its syringe). The holder should be strong enough for prolonged periods.



Key

- A. Single use sharps container
- B. Holder for the sharps container
- C. Installation of the holder
- D. Reusable Sharps Container

- 1. Container (empty drugs pot)
- 2. Lid
- 3. Triangular hole
- 4. Holder (PVC pipe)
- 5. Holes enabling the fixation of the holder
- 6. (Metallic) U-profile
- 7. Screws

Input

- Generic drugs container
- Glue (plastic or superglue)
- Cutter knife
- Velcro straps / PVC pipe (connector) with elastic band
- Metallic U-profile
- Screws
- Screwdriver

Remarks

- Sharps should be segregated where and when they are generated, by the (para-)medical staff (e.g. doctors, nurses, laboratory technicians, pharmacists).
- Needles should never be recapped after use because the risk of injuries is extremely high during this action.
- The right location of the sharps containers must be decided in close collaboration with the medical staff.
- A single use sharps container should be collected and brought to the waste zone for final disposal when it is $\frac{3}{4}$ full.
- Sharps should not be burnt in volume reducers or even in good auto-combustion incinerators as they will stay sharp and thus form a risk for injuries when the residues are removed from the furnace. This could potentially lead to an infection of the waste manager during the manipulation of other medical waste. The people emptying full residues (ash) pits that contain rusty sharps (metal of sharps will corrode after they have been exposed to high temperatures) could be exposed to Tetanus. Glass sharps often explode when they are burnt or incinerated, which can lead to injuries of the waste manager.
- The waste manager should discard the single use sharps containers within a sharps pit (T.B. 6.02). The containers can never be opened, emptied nor reused.
- Make sure there are always enough disposable sharps containers in stock, which are ready to use.
- The triangular hole of a self-made sharps container (modified drugs container) is not adapted to remove a needle from a Luer-lock syringe, because of its screw pitch.
- When generic drugs pots aren't available (in sufficient amount), or when people try to recycle them, the Reusable Sharps Container (RSC) can be an interesting alternative. This solid container corresponds to the specifications mentioned above and can be used for most kinds of sharps generated in health structures, including needles connected to Luer-lock syringes. However, sharps that are too long like the Auto-Disable (AD) syringes, (razor)blades with a long handle and very long needles (e.g. lumbar puncture needles) should not be introduced in the RSC because it will be very difficult to remove them afterwards. The RSC is provided with an opening mechanism that enables the safe disposal of the sharps in their designated pit. As the mechanism should be locked with a padlock, only the waste manager can open the container. To avoid sharps being stuck inside by overfilling the container, it has to be emptied regularly (daily or at least once a week if very few sharps are generated). Before the container goes into circulation again, its outside should be rinsed with clean water, washed with water and soap (detergent), rinsed again, disinfected with a 0.1% chlorine solution (T.B. 2.20) and rinsed a last time with clean water. A small amount of chlorine solution (1 - 2 ml) can also be left within the RSC to reduce blood stained sharps sticking to its inside. Make sure that the responsible (waste manager) will not try to introduce his hand inside the RSC to remove those sharps. Check that the padlock is put back and the key is removed before the RSC goes back into circulation (section 6.5 Further reading).
- As the needle can't be separated from Auto-Disable (AD) syringes (normally only to be used for immunisation activities), they have to be collected in their whole within cardboard safety boxes. The cardboard safety boxes must then be burned in a (temporary) safety box reducer (T.B. 6.03 and 6.04).
- Other long sharp objects like scalpels / razorblades with long handles and very long needles can also be collected in safety boxes and then burned in a safety box reducer (T.B. 6.03), or even collected in big modified drugs containers which can be discarded directly in the sharps pit.
- It is recommended to segregate (big) glass vials and ampoules in separate closable containers (big drugs pots or small buckets) in order to reduce their volume in specially designed glass crushers, placed directly on top of the sharps pit. For mass vaccination campaigns, the empty vials / ampoules should be encapsulated (section 6.5 Further reading).

T.B. 6.02 Sharps pit

Sharps are considered to be part of the most dangerous medical wastes. Metal sharps won't melt in an auto-combustion incinerator, stay sharp and sometimes even contaminated when the combustion is ineffective in inactivating heat-resistant micro-organisms. Glass sharps might explode in the fire and therefore become a danger for the operator and/or damage the incinerator. A sharps pit is a simple, efficient and safe facility for final disposal of sharps, at least if it's managed correctly (with complete encapsulation when the pit is nearly full).

Construction

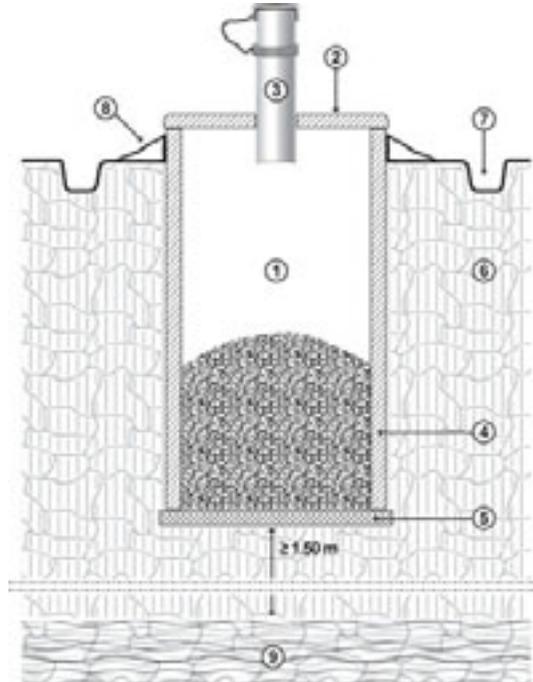
- Choose an appropriate place within the waste zone (T.B. 6.09) for the construction of a sharps pit. In case there would be a lot of glass to be disposed of (e.g. empty vials, ampoules), it's advisable to construct at least two sharps pits in order to have a reserve pit immediately available when the first one is filled up.
- Prepare the site for construction: remove all debris, flatten the surface, put up a (temporary) fence, do a soil texture test (T.B. 4.05) and bring in the needed construction material and equipment. Normally the preparation of the different waste zone facilities is done all at the same time.
- Lay out the area for the excavation of the sharps pit. The area should be larger than the actual size (lining) of the sharps pit itself. The sharp pit's volume is not only depending on the size of the health structure and the number of patients, but also on the type of interventions (e.g. in some places, most of the treatments are done by injections). An example on volume calculation is given below.
- Dig the pit and check that its bottom is more than 1.5 m above the highest possible water table. The depth of the water table can be estimated by verifying its level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe in the ground, as deep as 1.5 m beneath the required pit depth. When pulled out, the rod or (the earth inside) the pipe should be dry. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level.
- Cast a closed foundation in reinforced concrete (300 kg/m³; T.B. 2.05) with a minimum thickness of 0.2 m on the bottom of the pit.
- Line the pit completely from the bottom till the top (at least 0.1 m above the ground surface) with plain concrete rings that are cemented and preferably also bolted together (T.B. 2.04), or with closed masonry-work, made watertight with cement plaster (T.B. 2.05). For the outer surfaces of the sharps pit, only one 10 mm layer of cement plaster is required, whereas internally it is recommended to add a second 10 mm layer once the first one has dried.
- Backfill the space in between the lining and the excavated hole with gravel and compacted soil.
- Put a reinforced concrete slab on top of the pit's lining. This slab can be cast in situ as it should not be removable, or it can be made like a latrine slab (T.B. 3.05) and secured on the lining with a 10 mm layer of mortar. The slab should only have a round hole in the middle, large enough to fit the drop pipe.
- Place the drop pipe, with its diameter adapted to the available sharps containers and about 1 m in length, in the slab's hole and secure it with mortar. To ensure a better anchorage, a clamp can be connected to the drop pipe at the level where it will be mortared in the slab. Equip the drop pipe with a cover to avoid vectors and rainwater entering the pit.
- Add an impermeable layer (mortar or clay) against the aboveground part of the lining.
- Make a drainage channel around the pit to prevent runoff water entering and to protect its walls (although the pit should be more or less watertight with the complete lining).

Operation

- Dispose immediately of the sharps (with their disposable container) into the pit when they arrive at the waste zone. Make sure that the drop pipe's cover is always replaced after having disposed of the sharps.
- Close down the pit permanently when the level of the sharps is 0.30 m underneath the slab. The drop pipe should be cut at its base. Concrete or preferably a mixture of cement, lime and some water (weight ratio: 3, 3, 1) should be poured into the hole to encapsulate the sharps completely.

Example of the volume calculation

- 500 needles = about 1 l (safe estimation).
- If 500 needles are generated per week, the required pit size for 20 years will be:
 $1 \text{ l} \times 52 \text{ weeks} \times 20 \text{ years} = 1040 \text{ l} = \text{about } 1 \text{ m}^3$.
- Be aware however that single use sharps containers also take up quite some space as they can only be filled to $\frac{3}{4}$ of their volume. Other sharps like ampoules and vials require a lot of space as well, certainly when they are not crushed. So double or even triple the calculated useful volume!
- Don't forget to add a free space above the waste (at least 0.30 m deep) to allow complete encapsulation!



Key

Input

- | | |
|--|--|
| <ol style="list-style-type: none"> 1. Pit 2. Slab 3. Drop pipe with cover 4. Sealed lining 5. Sealed (closed) concrete foundation 6. Soil 7. Drainage channel 8. Impermeable layer 9. Water table | <ul style="list-style-type: none"> - Reinforcement bar or $\frac{1}{2}$" galvanised pipe and hammer - Shovels, hoes, picks, miner's bars - Concrete (300 kg/m^3) and reinforcement bars (foundation) - Concrete (rings), bricks or cement blocks, sand and cement or a metal / plastic recipient (drum) in the 1st phase - Material to bolt the rings together (spanners, bolts and nuts) - Reinforced concrete slab (potentially made in situ) - Pipe (PVC, metal; diameter: 110 - 150 mm) with a cover - (Temporary) fence material - Mason's tools - Protective clothing for operators |
|--|--|

Remarks

- Only dispose of sharps (with disposable container) in the pit. Do not throw in soft or organic waste.
- A watertight sharps pit also permits to discard very small amounts of recurrently generated hazardous waste (e.g. broken mercury thermometer, itself encapsulated within an empty plastic drugs container and covered with plaster or a cement – lime – water mixture).
- If the soil is unstable, reinforce the vertical walls with removable struts during the excavation or make the pit conical.
- Alternative methods:
 - If the subsoil is very rocky, the area flood prone or the water table high, the pit may have to be partially constructed aboveground in a very well compacted earth mound. A complete lining that is entirely watertight is essential (T.B. 3.12).
 - A sharps pit can also be made of a big round plastic / polyester reservoir that is normally used for water storage. Such a reservoir can even be put in the water table as it is completely watertight and corrosion resistant. But during the construction, a concrete layer should be poured on its bottom to weigh it down in order to avoid that the reservoir would float when standing in a high water table. A heavy concrete slab should still be installed on top of the plastic / polyester reservoir, in which the drop pipe is integrated. These kinds of reservoirs can't be used however when a safety box reducer (T.B. 6.03) will be installed on top of the sharps pit because of the damages that the hot ashes falling in would cause.
- The volume of the sharps pit should be calculated according to the amounts of sharps that will be generated over a period of at least 5 years.
- The diameter of the drop pipe is important: it should be possible to drop the unopened disposable sharps containers (e.g. modified drugs containers) inside the pit without any obstructions, or to fit the discharge outlet of a Reusable Sharps Container. The length of the pipe is to prevent people reaching in the pit, trying to recuperate sharps..
- The drop pipe, slab and surroundings should be cleaned regularly and preferably occasionally sprayed with a 0.1% chlorine solution (T.B. 2.20).
- In acute emergencies (e.g. temporary health structure in a camp) or within the first phase of medical waste management, it is possible to make a "sharps pit" out of a single or double 125 l plastic recipient or a 200 l drum (preferably plastic but metal can do as well). As it is a "temporary sharps pit", it is recommended to foresee some handles on the drum to be able to remove it afterwards. A hole adapted to the size of the available sharps containers should be made in the top cover of the recipient / drum and a drop pipe with a length of 1 m installed. A metallic pipe can be welded to a metallic drum with some external reinforcements. A plastic drop pipe can be glued in some kind of flange (purchased or self-made; section 6.5 Further reading) that can be connected to the recipient / drum with bolts. Another alternative is to make a concrete slab to anchor the drop pipe and to place the slab over the recipient / drum. The recipient / drum can (partly) be buried while the majority of the drop pipe has to stay aboveground. This temporary sharps pit is to be used as a normal model.
- In urban areas (e.g. slums) where there isn't enough space to make a permanent sharps pit, such a temporary model can be useful as well. With a reduced drop pipe length, the "transitory sharps pit" can also be located at a safe place aboveground where there isn't access for unauthorised personnel.
- Once the health structure is dismantled or the "transitory sharps pit" is $\frac{3}{4}$ full, the recipient / drum should be dug out and/or transported to a safer area (e.g. the waste zone of a long-term hospital or a controlled landfill) where it will need to be encapsulated with a cement, lime and water mixture (3, 3, 1 parts by weight) or concrete before final burial.
- Auto-Disable syringes and cardboard safety boxes that are used in the health structure within an immunisation program for instance, shouldn't be disposed as such in a sharps pit as they take up too much space. A safety box reducer, preferably in heat resistant bricks, should be constructed on top of the sharps pit, next to the drop pipe (T.B. 6.03). Make sure that the concrete slab is designed to withstand the additional weight of the volume reducer.
- In case a lot of glass waste is generated (e.g. ampoules, vials), a glass crusher should be installed on top of the sharps pit (section 6.5 Further reading). Contact your technical referent for more information.
- The operator (waste manager) should receive intensive training and a complete set of protective clothing, which should always be worn during operation and maintenance (T.B. 6.10).

T.B. 6.03 Safety box reducer

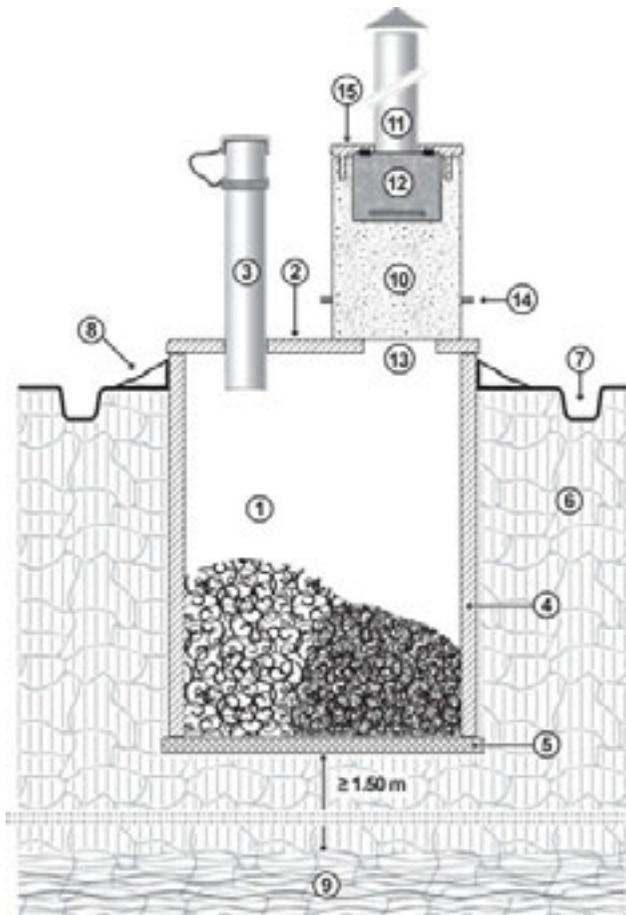
Sharps are considered to be part of the most dangerous medical wastes. The normal practice of sharps being discarded directly in a sharps pit is unfeasible for Enlarged Programs of Immunisation (EPI) because most often Auto-Disable (AD) syringes are used. As their needle can't be disconnected, the AD syringes represent a big volume that would fill up the sharps pit too fast. These syringes are therefore collected in cardboard safety boxes and burned in a safety box reducer. Its design is such that when the safety boxes are burned, the residues fall straight into the sharps pit, thus nobody gets in contact with the burnt sharps. Do take into consideration that glass sharps (e.g. vials, ampoules) might explode and therefore form a danger for the operator, thus they should not be collected in the safety boxes.

Construction

- Measure the size of the commonly used safety boxes and adapt the reducer design accordingly.
- Choose and prepare within the waste zone (T.B. 6.09) an appropriate place, and dig the sharps pit (as explained in T.B. 6.02). Take the dominant wind direction into consideration for its location to avoid smoke nuisances, and stay away from objects that can catch fire. Make the pit twice as large sideways or dig a separate sharps pit to accommodate the safety box reducer.
- Construct the sharps pit in concrete or "watertight" masonry-work as described above (T.B. 6.02). Its reinforced concrete slab on top should have a drop pipe next to a hole just as big as the internal surface of the safety box reducer (the standard size of the hole is two refractory bricks deep and one wide; normally 0.46 m x 0.23 m). The reinforced concrete slab should be able to resist the weight of the safety box reducer (the standard model can weigh up to 400 kg).
- Build two closed layers of refractory (heat-resistant) bricks around the hole in the concrete slab (section 6.5 Further reading). The bricks should be put together with a very fine layer of refractory cement (2 - 3 mm smeared directly on the refractory bricks). Keep the refractory bricks away from humidity and direct heat (e.g. direct sunlight) because the latter has a bad influence of the strength of the refractory cement.
- Foresee four openings in the refractory bricks when the third layer is constructed in a similar manner as described above. The four holes can be obtained simply by installing two refractory bricks $\frac{3}{4}$ in length in the middle of the long sides of the safety box reducer. The easiest way to obtain a $\frac{3}{4}$ refractory brick is to make a (small V-shaped) cut all around the brick and than break it in two with a good blow by means of a hammer and a flat chisel.
- Install a prefabricated grid, made out of reinforcement bars welded together.
- Build another three closed layers in a similar way as above.
- Build another five layers in a similar way as above, but the front side should be left open. Therefore, four bricks will have to be cut in half in the same manner as described above.
- Place a prefabricated metallic cover on top of the refractory bricks, which is foreseen with a hole for the chimney and a hanging loading door (potentially with locking mechanism).
- Construct an outer metallic hull or a normal brick wall around the refractory part of the safety box reducer, leaving a free space of some centimetres, and/or construct a roof above to protect it from harsh weather conditions (refractory bricks should not get wet).
- Fit a chimney with head cap on the hole in the cover. The chimney should be at least 2 m high and be secured to the fence of the waste zone or with cables to the ground.

Operation

- Open the loading door and check if residues from the previous cycle are remaining in the safety box reducer. Push them down into the sharps pit with a long solid poking bar before starting a new cycle.
- Place a closed safety box on its side via the loading door within the reducer.
- Pour some kerosene over the safety box, mainly on and around its handle.
- Light the safety box at its handle and check if the fire takes well. In case the fire would die out, some extra combustibles like paper, cardboard and dry coconut shells or wood can be added to help starting the combustion.
- Close the loading door when a good fire has started.
- Monitor the combustion, but be careful for explosions when glass sharps would accidentally have been included in the waste. As the combustion progresses, the residues should fall straight in the pit.



Key	Input
1. Pit	- Reinforcement bar or ½" galvanised pipe and hammer
2. Concrete slab	- Temporary fence material
3. Drop pipe with cover	- Shovels, hoes, picks, miner's bars,
4. Sealed lining	- Concrete (300 kg/m ³), reinforcement bars (foundation)
5. Sealed (closed) concrete foundation	- Concrete rings or bricks / blocks, cement and sand
6. Soil	- Reinforced concrete slab (300 kg/m ³) or made in situ
7. Drainage ditch	- Pipe with cover (PVC, metal; ø: 110 or 150 mm)
8. Impermeable layer (mortar)	- Refractory bricks and refractory cement
9. Water table	- Mason's tools, including hammer and flat chisel
10. Safety box reducer	- Steel frame with vertical loading door, metal grid
11. Chimney with head cap	- Chimney and head cap
12. Vertical loading door	- Protective clothing for builders and operators
13. Disposal hole for residues to fall in the pit	
14. Grid (at 3 rd layer)	
15. Metallic cover	

Remarks

- The design of the safety box reducer should permit that the residues with the burned needles fall directly into the sharps pit. The vertical entrance and its size should allow that only one safety box can be loaded at the time, rendering the access difficult for the recipients of other kinds of waste.
- Although the safety box reducer is similar to the principle described in T.B. 6.04 (Mass vaccination campaign waste), this device should not be used to reduce the sharp waste generated during big campaigns because the sharps pit designed for long-term use would fill up too fast.
- The volume of the sharps pit should be calculated according to the amounts of sharps that will be generated over a period of at least 5 years. Take into consideration that the residues of burned safety boxes do take up more space than individual needles. When a correct combustion takes place, a volume reduction of at least 90% should be obtained (the residues volume < 10% of the original safety box volume).
- Important: foresee an additional depth of 0.30 m in the calculation of the pit size for final encapsulation. It is not part of the effective pit volume.
- Refractory cement can be aggressive. It is thus recommended to wear the needed protective clothing during the construction process (at least thin gloves).
- It is also possible to make a safety box reducer from a metal 200 l drum.
- To avoid that the safety box reducer and its waste load get wet (and hence is more difficult to burn), a roof should be constructed above, if possible. Do not use combustible building material for the roof.
- Use this reducer only for safety boxes containing Auto-Disable (AD) syringes, and potentially very long needles, scalpels and razorblades with a long non-detachable plastic handle that don't fit in a normal sharps container. Never put organic waste (e.g. placentas, food residues), explosive objects (e.g. aerosol cans) and/or materials that give off toxic fumes (e.g. drugs) in the safety box reducer.
- As glass might explode when heated, it shouldn't be burned in the safety box reducer. In case there would be a lot of glass waste (e.g. empty vials, ampoules) being generated, it's advisable to construct at least a second regular sharps pit from the beginning in order to have a reserve one immediately available when the first one is filled up. A glass crusher directly installed above the sharps pit (section 6.5 Further reading) will allow a drastic volume reduction of the glass waste, resulting in a longer lifespan of the pit. Contact your technical referent for more information.
- The sharp waste should be eliminated as soon as possible once it's brought to the waste zone.
- Do not add any other potential safety boxes before the first one is really burning well.
- If residues remain in the safety box reducer, the air draught might be hindered during the next cycle, with a bad combustion as a result. Do not empty the safety box reducer via the loading door, but push the possible remaining residues downwards with a poking bar before starting the next combustion cycle.
- The operator of the safety box reducer (waste manager) should receive intensive training and a complete set of protective clothing, which should always be worn during operation and maintenance (T.B. 6.10).

T.B. 6.04 Mass vaccination campaign waste (temporary safety box reducer)

Most of the waste generated during mass vaccination campaigns are sharps. Sharps are considered to be very dangerous medical waste. The normal practice of sharps being discarded directly in a sharps pit is unfeasible during mass vaccination campaigns because most often Auto-Disable (AD) syringes are used. As their needle can't be disconnected, the AD syringes represent a big volume that would fill up the sharps pit too fast. These syringes are therefore collected in cardboard safety boxes, transported to a centralised place and burned in a temporary safety box reducer. Its design is such that when the safety boxes are burned, the residues fall straight into a pit, thus nobody gets in contact with the burnt sharps. Do take in consideration that glass sharps (vials, ampoules) might explode and therefore form a danger for the operator. Thus, it's strongly recommended that this kind of waste is disposed of by encapsulation without treatment.

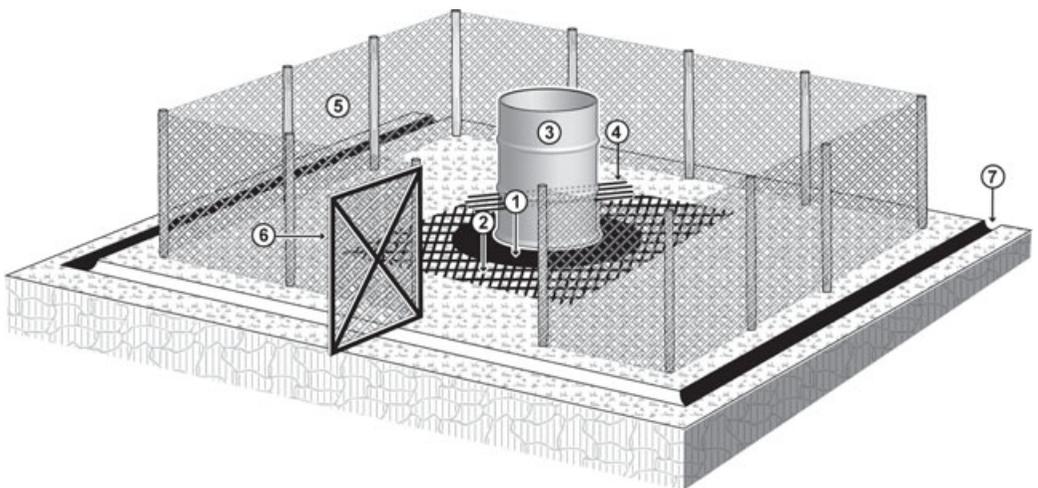
Construction

- Cut the upper and bottom lids completely out of a metallic 200 l drum to obtain an open cylinder, which will become the temporary safety box reducer. Make sure that the sharp edges are worked in such a way that they can't injure the operator.
- Make 10 holes in the circumference of the cylinder at about 1/3 of its height. As such, five metallic reinforcement bars can be slid parallel to each other in the drum.
- Cut the upper lid completely out of another metallic 200 l drum to make a container that will collect the burnt residues. Make sure that the sharp edges are worked in such a way that they can't injure the operator.
- Choose an appropriate place for the installation of the temporary safety box reducer, preferably within an existing waste zone (T.B. 6.09). Take the dominant wind direction in consideration to avoid smoke nuisances and stay away from objects that can catch fire.
- Dig a hole according to the size of a 200 l drum and place the residues collection drum inside. Its top should just be reaching the surface.
- Put two metallic beams or a metallic grid with rather large holes (at least 0.1 m x 0.1 m) over the collection drum. The material used should be strong enough to support a metallic 200 l drum full of filled up safety boxes. Be aware that the metal of the grid might get hot, loose partly its rigidity and potentially bend.
- Put the temporary safety box reducer on top of the metallic beams or grid.
- Make sure there is a fence around this temporary facility and allow only access to authorised personnel in order to avoid accidents.
- Make a drainage channel around the whole facility to prevent runoff water entering in the pit.
- Make sure there is also a short term but safe storage place nearby for the safety boxes, with a roof during the rainy season because it is essential to keep the big amount of waste dry.

Key	Input
1 Pit (with open metallic drum integrated)	- Shovel, hoe, pick axe, miner's bar
2. Metal grid or beams on top of the pit	- Poles, fence material
3. Metal drum 200 l (completely open cylinder)	- At least 2 metal drums of 200 l (e.g. fuel drum)
4. Metal grill in drum (5 parallel bars)	- Cold chisel and hammer
5. Fence	- Metal saw
6. Entrance with door	- Pair of pincers and wire
7. Drainage channel	- Heavy grating / reinforcement bars / beams
	- Poking bar
	- Combustibles: kerosene, paper, dry coconut shells, wood
	- Matches or lighter
	- Concrete or a mixture of cement, lime and water
	- Tools to prepare the mixture
	- Protective clothing for the manufacturers and operators

Operation

- Push, by means of a poking bar, the potential remaining residues of the temporary safety box reducer into the collection drum, before starting a new cycle.
- Place a closed safety box inside the temporary safety box reducer and pour some kerosene on and around its handle.
- Light the safety box at its handle with a piece of burning paper and give the fire the time to take well. In case the fire would die out, some extra combustibles like paper, cardboard and dry coconut shells or wood can be added to help starting the combustion.
- Add some more safety boxes onto the fire once a nice combustion has started.
- Monitor the combustion from a distance, and be careful for explosions when glass sharps would accidentally have been included in the safety boxes.
- Keep on monitoring with precaution and add batches until all safety boxes have been burnt or until the end of the working period. In case the residues don't fall into the pit, push them down with a poking bar.
- Remove the safety box reducer and the beams / grid when the collection drum inside the pit is filled up to 4/5 of its height, or when all the safety boxes are burnt. It is recommended to strike the safety box reducer a couple of times with the poking bar or a hammer, so that some last sharps might fall into the "pit". In case all the waste has been burnt, consider the alternative to bury also the grid and the safety box reducer.
- Encapsulate the residues by pouring concrete or preferably a mixture of cement, lime and some water (weight ratio: 3, 3, 1) inside the collection drum and once settled, cover everything with compacted earth.



Remarks

- During a mass vaccination campaign, it is a common policy to bring back all the waste to a safe centralized place, where the quantity will potentially be checked by the medical staff and where it can also be eliminated. It is therefore interesting to choose as centralised place a health centre with an existing waste zone. The safety box reducer can be situated within or next to this waste zone, and its location should be where its smoke won't bother the health services nor the population.
- If needed, place the burner underneath some kind of roof (do not use combustible building material) to avoid that the waste load gets wet (and thus is more difficult to burn).
- The amount of safety boxes to be burnt during a mass vaccination campaign is often that high that a single residues collection drum won't be sufficient. In that case, a trench with several collection drums will need to be prepared. Attention needs to be given that nobody, including the operator can't fall in the open drums.
- When there aren't enough drums available, other material (e.g. concrete rings, bricks) to line the pit should be looked for to permit a correct encapsulation afterwards. In the worst case scenario, the temporary safety box reducer can also be placed directly over the pit, which bottom should preferably be more than 1.5 m above the water table. The depth of the water table can be estimated by verifying its level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe in the ground, as deep as 1.5 m beneath the required pit depth. When pulled out, the rod or (the earth inside) the pipe should be dry. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level.
- In case of an extremely big mass vaccination campaign, several temporary safety box reducers can be put together and be used simultaneously to speed up the elimination process.
- The complete temporary safety box reducer facility should be ready before the first waste arrives.
- The waste should be eliminated as soon as possible once it has arrived at the centralized place, but only after clearance by the medical staff .
- Never over-fill the reducer with safety boxes as this could hinder the free air circulation (causing a lack of oxygen), resulting in a bad combustion. Thus, it is better to burn small numbers of safety boxes at the time and gradually introduce new batches.
- When a correct combustion takes place, a volume reduction of at least 90% should be obtained (the residues volume <10% of the original safety box volume). Volume reductions up to 96% have already been noticed.
- Wet cotton balls, used to clean the skin before vaccination, can be collected in a carton and burned in the temporary safety box reducer. However, it is probable that some additional combustibles will be needed.
- As glass might explode when heated, the vials or ampoules generated during the mass vaccination campaign shouldn't be burned in the temporary safety box reducer. It is recommended to encapsulate them immediately in drums (after having been counted by the medical staff), which should be buried within the same waste zone where the safety boxes are treated, or in a controlled tip (T.B. 5.03) or a sanitary landfill.
- Never put organic waste (e.g. placentas, food residues), explosive objects (e.g. aerosol cans) and/or materials that give off toxic fumes (e.g. drugs) in the temporary safety box reducer. Always seek advice from your technical referent before, in case of doubt.
- If residues remain in the temporary safety box reducer, the air draught might be hindered, with a bad combustion as a result. Therefore, push the remaining residues downwards with a poking bar, before starting a new burning cycle.
- The temporary safety box reducer and the potential open part of the pit should be covered when not in use, in order to avoid that residues would be blown away by the wind.
- The operator of the temporary safety box reducer (waste manager) should receive appropriate training and a complete set of protective clothing and equipment, which should always be used during operation and maintenance of the facility (T.B. 6.10).

T.B. 6.05 Temporary volume reducer

As soft waste represents the biggest quantity of all the medical waste that is generated in a health structure, it's important to reduce its volume drastically before it is finally disposed of into a residues (ash) pit. In an acute emergency, a temporary volume reducer can achieve this objective efficiently. A permanent incinerator should replace the temporary volume reducer if the health structure becomes permanent.

Construction

- Obtain a 200 l metal drum.
- Cut out its top cover over around 2/3 of its perimeter. Keep the cut out as it will be used as the loading door.
- Cut a hole in the remaining part of the top cover. Its size should be adapted to the diameter of the chimney that will be installed (minimum 100 mm).
- Cut out a panel of about 0.4 m wide x 0.25 m high at the lower part of the drum's cylinder. Keep the cut out panel because it will be used as the ash door.
- Prepare a metal plate with a length that is equal to the internal height of the drum and a width that is the same as the straight part of the loading door.
- Perforate the metal plate over its complete surface with 10 mm holes about 20 mm apart from each other.
- Make sure that all the sharp edges of the drum, the loading door, the ash door and the perforated plate are worked in such a way that they can't injure the operator.
- Slide the perforated plate into the drum and fix it to divide the inside into two chambers of unequal volume.
- Connect the loading door to the top of the drum with a hinge mechanism (e.g. solid hinges with a minimal size of 50 mm) and attach a handle so that it may be opened and closed easily. The handle should be designed in such a way that the loading door cannot pivot towards the inside of the drum.
- Join the ash door with a hinge mechanism to the bottom of the drum and install a handle, designed in such a way it can be attached to the drum's cylinder.
- Cut some rigid metal grating to the same size as the inner cross section of the large chamber (in front of the perforated metal plate), and fix it horizontally about 0.2 m from the bottom of the drum. The grating will separate the soft waste from the ash part of the volume reducer.
- Fit the chimney solidly on the hole that is made in the drum's top cover. The chimney must be at least 2 m high, and equipped with a head cap.

Operation

- Collect all the soft waste bins before the burning is started.
- Remove the ashes of the previous cycle via the ash door and discard them in the residues pit (T.B. 6.07).
- Open the loading door and put some paper, cardboard and combustibles (e.g. dry firewood, dried coconut shells) in the volume reducer. Some kerosene can be added as well to ease the lighting of the fire.
- Close the loading door.
- Light the paper / cardboard through the ash door. Once the fire takes off, the ash door can be closed. Give the fire the time to take well.
- Introduce via the loading door a small batch of soft waste (equivalent to the content of a waste bin) once the fire is burning well.
- Close the loading door immediately again.
- Monitor the combustion. If the fire would start to die out, add via the loading door some combustibles like dry wood or coconut shells.
- Introduce a second batch of soft waste when the first one is nearly completely burnt.
- Keep on monitoring the combustion and adding small batches of soft waste as described above.
- Let the fire die out by itself once all the waste is burnt.
- Rinse the soft waste bins with clean water, wash them with water and soap (detergent), rinse again, disinfect with a 0.1% chlorine solution (T.B. 2.20) and rinse a last time with clean water, before they go into circulation again.

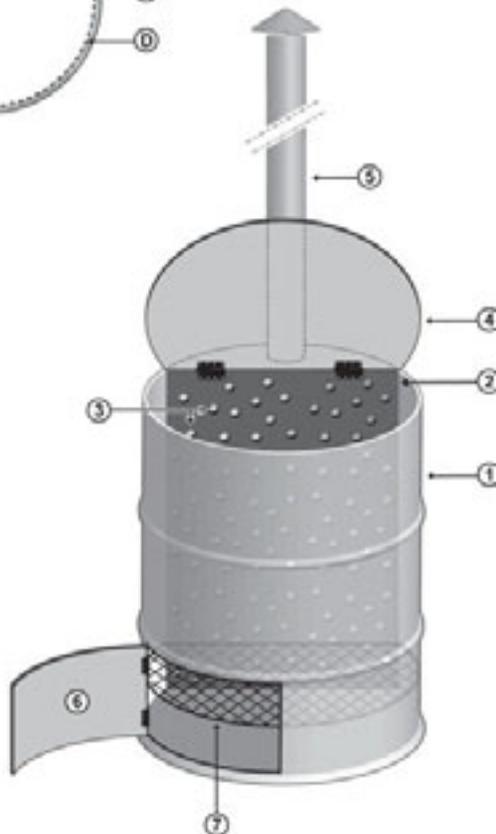
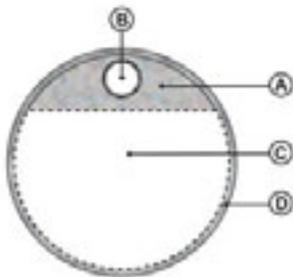
Key

Input

- A. Top of the drum (part not cut out)
- B. Hole for the chimney
- C. Combustion chamber (large)
- D. Cut-out of the cover

- 1. Metal drum, 200 l
- 2. Perforated metal plate
- 3. Perforations in the metal plate for draught
- 4. Loading door
- 5. Chimney with head cap
- 6. Ash door (can be used to regulate the draught)
- 7. Metal grating (or heavy mesh)

- Metal drum of 200 l (e.g. fuel drum)
- Hammer
- Metal saw or cold chisel
- Pair of pincers and wire
- Metal plate (same thickness as drum)
- Spanners, file
- Drill machine with drill bits or large punch
- System to fix the hinges, perforated plate and chimney to the drum (e.g. nuts and bolts, welding machine)
- Metal chimney pipe and head cap
- Heavy mesh, grating or reinforcement bars
- 4 solid metal hinges or an alternative
- Paper, cardboard, kerosene, dry coconut shells, wood
- Matches or lighter
- Scoop and brush to collect residues
- Protective clothing for operators



Remarks

- Place the temporary volume reducer in the foreseen waste zone, at a location where the smoke won't bother the health services nor the neighbouring population. The required height of the chimney depends on the surrounding obstacles (e.g. buildings and vegetation), so its outlet should normally be above them.
- Alternative: it's possible to remove the bottom of the drum completely and to place the volume reducer immediately over the residues (ash) pit by means of metallic beams or a metallic grid with big holes (at least 0.1 m x 0.1 m). The material used should be strong enough to support a metallic 200 l drum full of waste. Be aware that the metal of the grid might get hot, loose partly its rigidity and potentially bend. This system has the advantage that all the residues fall immediately in the pit, although it might still be necessary to push them down before a new combustion cycle is started. The inconvenience is that the residues pit can't be closed easily at the end of a cycle and ashes could be blown away by the wind.
- Place the volume reducer underneath a roof (do not use combustible building material) to avoid that the waste load gets wet during the rainy season and thus is more difficult to burn. The roof also helps to reduce a little bit the drum corrosion.
- Even under the best circumstances, a drum volume reducer that is frequently used will not last very long. This is due to corrosion, enhanced by the corrosive gasses that are generated when burning soft waste and the heat produced inside the drum.
- Clean out the ash part of the volume reducer before each new cycle is started, otherwise the air draught will be hindered, resulting in a bad combustion. Do not empty the volume reducer via the loading door.
- Do not try to over-economize on combustibles (e.g. paper, cardboard, dry firewood, dried coconut shells): always preheat the volume reducer and keep a good fire going to guarantee the best combustion possible.
- Never over-fill the temporary volume reducer with soft waste: this would block the free circulation of air (causing a lack of oxygen), resulting in a bad combustion and thus more toxic fumes. Thus, it is better to burn small batches (e.g. content of a 20 l waste bin) at the time and once they are nearly completely burned, a new batch can be introduced.
- The opening of the ash door may be adjusted to regulate the draught. However, it is preferable to burn with the ash door closed, if the draught is sufficient.
- When a correct combustion takes place, a volume reduction of at least 90% should be obtained (the residues volume < 10% of the original volume).
- Never burn sharps (e.g. needles, scalpels, ampoules, vials), organic waste (e.g. placentas, food residues), explosive objects (e.g. aerosol cans) or materials that give off toxic fumes (e.g. drugs) in a volume reducer. Other facilities should be available (see appropriate Technical Briefs) in the waste zone to dispose of them. In case of doubt, always seek advice from your technical referent.
- The operator of the temporary volume reducer (waste manager) should receive an appropriate training and a complete set of protective clothing and equipment, which should always be used during operation and maintenance of the facility (T.B. 6.10).

T.B. 6.06 Permanent batch incinerator

As soft waste represents the biggest quantity of all the medical waste that is generated in a health structure, it's important to reduce its volume drastically before it is finally disposed of into a residues (ash) pit. A permanent, mostly auto-combustion incinerator should not only achieve this treatment objective, but in comparison with a volume reducer also render the remaining solid residues and fumes:

- more decontaminated (exempt of pathogens).
- less offensive (unrecognisable solid residues / the emissions the least toxic possible with limited means).

Principle

The "ideal" permanent incinerator for normal sized health structures within low-income countries should respond to the following specifications:

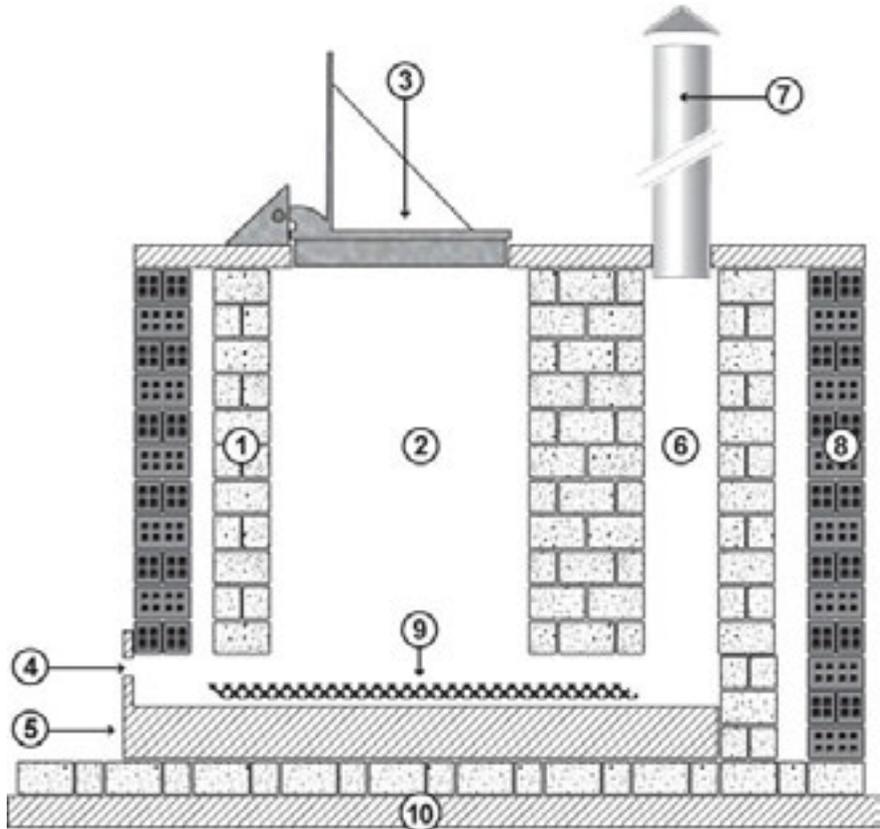
- Composed of a primary and secondary combustion chamber to extend the retention time of the gasses in a hot environment. It allows to drastically reduce the number of thermo-resistant pathogens and to burn off more (toxic) emissions.
- Build in refractory material (heat resistant bricks and cement) to extend its lifetime and to have less temperature variations when new or wet waste is introduced.
- Simple design using appropriate technology.
- Affordable at purchase and low running and maintenance costs.
- Able to reach at least 850 °C during incineration.
- Able to incinerate at least 10 kg of soft waste per hour.
- Consists of an auto-combustion system, which functions mainly on the burnable waste and doesn't need additional fuel, except during the start up phase to preheat the incinerator, and when extremely wet or some specific (bio-)hazardous waste has to be incinerated. It results in an important reduction of the amount of additional combustibles needed.

Always seek advice from your technical referent in case of doubt for the choice of an appropriate incinerator.

Operation

For factory made incinerators, the instructions from the manufacturer should be followed precisely. Below is a general description of how to use a batch auto-combustion incinerator (e.g. the De Montfort):

- Make sure all the soft waste bins have been collected before the incineration starts.
- Empty the ashtray containing ashes and residues from the previous incineration cycle into the residues (ash) pit (T.B. 6.07). An extra sweep inside the incinerator with a long-handle broom might be necessary to remove residues that fell beside the ashtray.
- Open the loading door and put some paper, cardboard and combustibles (e.g. dry firewood, dried coconut shells) in the incinerator.
- Close the loading door.
- Light the paper / cardboard through the ashtray door. Once the fire takes off, close the ashtray door.
- Give the fire the time to take well and to preheat the incinerator. The preheating should last until a roaring fire is heard or at least until good flames are visible in the secondary combustion chamber (this can be seen via the peephole at the back side of the incinerator, if available).
- Introduce via the loading door a small batch of soft waste (equivalent to the content of a waste bin), once the fire is burning well.
- Close the loading door immediately again.
- Monitor the combustion in the primary and secondary combustion chambers (if possible): if the fire would start to die out in one of the chambers just after a new batch of waste went in, add via the loading door some combustibles like dry wood or coconut shells.
- Introduce a second batch of soft waste when the first one is nearly completely burnt.
- Keep on monitoring the combustion and adding small batches of soft waste as described above.
- Let the fire die out by itself once all the waste is burnt.
- Rinse the soft waste bins with clean water, wash them with water and soap (detergent), rinse again, disinfect with a 0.1% chlorine solution (T.B. 2.20) and rinse a last time with clean water, before they go into circulation again.



Key

1. Refractory bricks
2. Primary combustion chamber
3. Loading door with handle
4. Air inlet
5. Ashtray / door
6. Secondary combustion chamber
7. Chimney with head cap
8. External wall (bricks, metal hull)
9. Grate
10. Concrete slab

Figure adapted from the De Montfort incinerator

Never modify existing plans / models on your own initiative!

Remarks

- Skilled people are needed for the construction of incinerators. Since refractory cement can be aggressive, it is recommended to have the builders wear the needed protective clothing during the construction process (at least thin gloves).
- If refractory bricks and cement aren't available on the spot, look in neighbouring countries or order from high-income countries (e.g. in Europe). Correct refractory bricks for batch (auto-combustible) incinerators have a high density (weight of about 4.5 kg/brick) and are made out of kaolin enriched with alumina (Al_2O_3 ; concentration ideally around 60%). This material has a high resistance to temperature variations, which occur each time a new batch of soft waste is manually introduced via the loading door.
- Position the incinerator in the foreseen waste zone, at a location where the smoke won't enter the health structure's buildings nor bother the neighbouring population.
- The required height of the chimney (preferably in stainless steel or thick plated metal tubes) depends on the surrounding objects (e.g. buildings and vegetation), with its outlet always well above them. Be aware that a higher chimney creates more draught, which has an influence on the combustion temperature (can be positive or negative). The admission of air is also function of the size of the air inlets.
- Position the incinerator underneath a roof (do not use combustible building material) to avoid that the waste load gets wet and thus is more difficult to incinerate. The roof also helps to reduce the corrosion of the (hot) metallic parts of the incinerator.
- Big incinerators take longer to preheat and therefore need a lot more combustibles, thus it is advisable to construct (rather) small incinerators. For large health structures where the capacity of a small incinerator doesn't seem to be sufficient, it is often more appropriate to build two small ones than one big incinerator. Only for very big hospitals (> 300 beds), larger models of commercially available incinerators might be needed.
- Do not scale up the size of existing designs because this might have serious consequences on the efficacy of the incinerator.
- Empty the incinerator's ashtray each time before a new incineration cycle is started, otherwise the draught will be hindered, resulting in a bad combustion with more toxic fumes. Do not empty the incinerator via the loading door.
- Do not try to over-economize on combustibles: always preheat the incinerator and keep a good fire going to guarantee the best combustion possible.
- Never over-fill the incinerator with soft waste: this would block the free circulation of air (causing a lack of oxygen), which would result in a bad combustion and thus more toxic fumes. Thus, it is better to incinerate smaller batches at the time and once they are nearly completely incinerated, a new batch can be introduced.
- When a correct combustion takes place, a volume reduction of at least 90% should be obtained (the residues volume <10% of the original volume).
- Never incinerate sharps (e.g. needles, scalpels, ampoules, vials), organic waste (e.g. placentas, food residues), explosive objects (e.g. aerosol cans) or materials that give off toxic fumes (e.g. drugs) in a batch (auto-combustion) incinerator. Other facilities should be available (see appropriate Technical Briefs) in the waste zone to dispose of them. In case of doubt, always seek advice from your technical referent.
- Bio-hazardous waste like tuberculosis sputum and blood can be incinerated if enough fuel (e.g. dry wood or coconut shells) are added to compensate for the heat loss due to the liquid nature of the waste. Always seek advice from your technical referent in case of doubt
- Attention: when the loading door is opened, a big flame might shoot out. Some flames might be noticed as well via the air inlet when the loading door is closed again. The operator should stand away from the flames.
- The operator of the incinerator (waste manager) should receive an intensive training and a complete set of protective clothing and equipment, which should always be used during operation and maintenance (T.B. 6.10).

T.B. 6.07 Residues (ash) pit

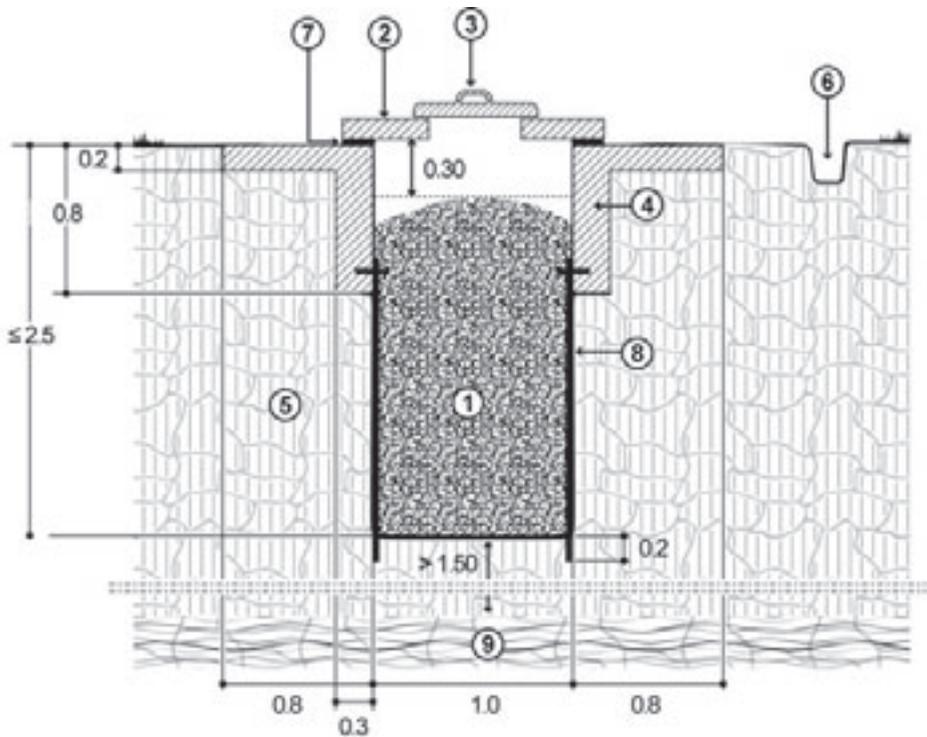
When soft waste is burnt in an incinerator or a (temporary) volume reducer, ashes and some unburned residues will be generated, thus an appropriate final disposal method is required. The ash pit is a simple and efficient facility for these residues and it corresponds to the principle of onsite final disposal. A simple (unlined) pit with a temporary slab can do for acute emergencies. A longer lasting solution as described below is required however for chronic emergencies and stabilised situations.

Construction

- Determine the amount of residues to be disposed of, based on the average volume of soft waste that is generated on a daily basis.
- Determine the required capacity of a single residues pit; after a correct combustion, the residues volume should represent less than 10% of the original volume. The suggested lifespan is two years at least.
- Choose within the waste zone (T.B. 6.09) an appropriate place to construct the residues pits, nearby the volume reducer / incinerator. It is recommended to construct at least two ash pits from the beginning in order to have a reserve readily available when the first one is full.
- Prepare the site for construction: remove all debris, flatten the surface, implement a soil texture test (T.B. 4.05), determine the depth of the water table and bring in the needed material. Usually the preparation of the different waste zone facilities is done at the same time.
- Prepare, excavate and line the pit in a similar way as described for a simple pit latrine (T.B. 3.04) or a VIP latrine (T.B. 3.07), depending on the soil type and the skills of the mason. The same excavation can be used to construct the two residues pits at the same time when a closed separation wall is built in the middle. In case the water table doesn't permit deep excavation, each pit can be increased in size by foreseeing two or more standard size slabs next to each other. In this case, it isn't necessary to put a closed separation wall in between each "cubicle". The layer of lean concrete for stabilisation on the bottom of the pit (VIP construction method) is recommended however.
- Make a concrete standard size slab (T.B. 3.05 or 3.08, depending on the type of lining, but without the ventilation pipe). The drop hole's shape and size (square of about 0.3 m x 0.3 m), hence the location of the reinforcement bars need to be modified. Provide a lid for the drop hole, preferably connected to the slab with some kind of heavy-duty "hinges". The lid can be made in wood (emergency situations), but preferably in concrete or metal.
- Install the prefabricated slab with its lid on the residues pit's lining / base, once it has settled for at least 3 days. To ensure a secure seating, the slab should be fixed to its lining / base (overlaps of at least 0.1 m) with a 10 mm thick mortar layer (T.B. 2.05).
- Make a drainage channel around the pit to lead runoff water away, protecting its walls against erosion.

Operation

- Remove the ashes and other residues from the incinerator / (temporary) volume reducer before a new cycle is started, and dispose of them in the residues pit. Make sure that the residues are always covered with the slab's lid or by at least 0.1 m of compacted soil when there is no slab (emergency situations).
- Close down the pit when the residues' level is about 0.3 m underneath the slab. For acute emergency settings, remove the temporary slab, put a metal grid on top of the residues and backfill the remaining space with compacted soil. Coming across the grid during future excavations will indicate that a pit has already existed on the same spot. In chronic emergencies and stabilised situations, the remaining space needs to be backfilled with soil without removing the concrete slab. It is possible to empty a residues pit that has been closed down for at least two years. However, special precautions should be taken to avoid injuries with sharps that have accidentally been discarded in the residues pit. The residues can be taken to a controlled tip (T.B. 5.03) or sanitary landfill.



Key

1. Pit
2. Slab
3. Lid
4. Base / lining
5. Soil
6. Drainage channel
7. Mortar layer (at least 10 mm thick)
8. Corrugated iron sheets (pit reinforcement)
9. Water table

Input

- String line, sticks and measuring tape
- Shovel, hoe, pick axe, miner's bar
- Fired bricks / cement blocks and/or sand, cement, gravel and clean water
- Reinforcement bars (diameter 8 mm)
- Tools to prepare and cast concrete; mason's tools
- Jute sacking or plastic sheeting
- Prefabricated slab with lid
- Protective clothing for operators
- Experienced mason and 1 or 2 labourers

Dimensions are indicated in m

Lining represented in the figure is similar to the method used for a simple pit latrine (T.B. 3.04), but also other methods can be used (e.g. T.B. 3.07).

Remarks

- Wood ash can be used for several purposes (e.g. covering excreta for odour reduction in latrines, hand washing), but the ash from incinerated / burnt soft waste should only be discarded at a safe place.
- If the pit is dug in one time until the required depth and the soil is unstable, the vertical walls should be reinforced with removable struts during the excavation, or the hole should be made conical.
- The bottom of the pit should be at least 1.5 m above the highest possible water table. The latter can be estimated by verifying the water level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe in the ground, as deep as 1.5 m beneath the required pit depth. When pulled out, the rod or (the earth inside) the pipe should be dry. If not, the pit depth should be adapted accordingly. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level.
- Another construction method for residues pits is the individual circular-shaped pit, which is often more difficult to excavate but less due to collapse because of its natural arching effect. This can be particularly interesting for emergency residues pits that won't be lined. When necessary, the circular pit can be reinforced with one or more concrete rings (T.B. 2.06). Other valid construction methods and materials exist for circular pits, but fall out of the scope of these guidelines. Contact your technical referent for more information.
- Alternative methods:
 - If the subsoil is very rocky, the area flood prone or the water table high, the pit may partially be constructed in the ground and the remaining aboveground part in a very well compacted earth mound. A different technique (T.B. 3.12) will have to be used. For big health structures generating large quantities of incinerator residues, long aboveground "trenches" might be more appropriate.
 - A residues pit can also be made of a big round plastic / polyester reservoir that is normally used for water storage. Such a reservoir can even be put in the water table as it is completely watertight and corrosion resistant. But during the construction, the reservoir should be weighted down (e.g. with a concrete layer or big stones on its bottom) in order to avoid that it would float when standing in a high water table. Hot ashes should not be discarded in such a residues pit.
- If it rains a lot in the region, the lining / base can be made a little higher aboveground, for the pit to be less at risk of flooding.
- The calculated pit volume should include a free space above the residues of at least 0.30 m high. It isn't part of the effective pit volume, but will allow the pit to be closed properly once it's nearly full.
- For acute emergencies, a temporary wooden slab or layers of compacted earth can do. For chronic emergencies and stabilised situations, a concrete standard size slab is recommended as it still has a reasonable weight that can easily be removed.
- For a large pit with several slabs, each one should have its own covered 0.3 m x 0.3 m drop hole, allowing an equal residues repartition over the pit. All of the slabs have to be sealed to each other with mortar.
- Only discard incinerated / burnt residues of soft waste in the pit. Do not throw in any other kinds of waste, and certainly not sharps!
- It is essential that the residues are covered immediately after disposal, to avoid that the wind would blow the ashes away (causing potentially respiratory infections) and/or that unburned residues would attract vectors (e.g. flies).
- The slab and surroundings should be cleaned regularly.
- The operator (waste manager) should receive intensive training and a complete set of protective clothing, which should always be worn during operation and maintenance (T.B. 6.10).
- If a residues pit is emptied (at least two years after it has been closed down), all its slabs should be removed to permit easy access and safe working conditions. Once all the slabs are removed, wait some time before entering into the pit to evacuate all potential hazardous gasses.
- During works within a used residues pit, make sure that the person inside the pit has a strong rope around his waist. This rope permits colleagues standing at the side of the pit to lift the person out if something goes wrong.

T.B. 6.08 Organic waste pit (“Placenta” pit)

Organic waste contains too many liquids to be suitable for incineration with volume reducers or batch auto-combustion incinerators. The temperature reduction due to the evaporation of the liquids will result in the formation of more toxic gases, the survival of potential thermo-resistant pathogens or even in bringing the combustion to a halt. Hence, many combustibles will be needed for the correct incineration of organic waste. Burial (with natural decomposition) is a simpler and more efficient disposal method. “Individual burial” would be too time consuming, but “collective burial” in an organic waste pit is appropriate.

Construction

- Determine over a period of at least a week, the volume of organic waste that needs to be disposed of.
- Determine the required capacity of a single organic waste pit, based on the daily average amount of organic waste. The suggested lifespan is 2 years at least.
- Choose an appropriate place within the waste zone (T.B. 6.09) to construct the organic waste pits. It is strongly recommended to construct at least two organic waste pits from the beginning in order to have a reserve immediately available when the first one is full.
- Prepare the site for construction: remove all debris, flatten the surface, implement soil texture and permeability tests (T.B. 4.05), determine the depth of the water table and bring in the needed material and equipment. Usually the preparation of the different waste zone facilities is done all at the same time.
- Prepare, excavate and line the pit in a similar way as described for a simple pit latrine (T.B. 3.04) or a VIP latrine (T.B. 3.07), depending on the soil type and the skills of the mason. The same excavation can be used to construct the two organic waste pits at the same time when a watertight separation wall is built in the middle. In case the water table doesn't permit deep excavation, each pit can be increased in size by foreseeing two or more standard size slabs next to each other. In this case, it isn't necessary to put a separation wall in between each “cubicle”. The layer of lean concrete for stabilisation on the bottom of the pit is highly recommended for the VIP construction method however.
- Make a concrete standard size slab with ventilation hole (T.B. 3.08), but the drop hole's shape and size (about 0.3 m x 0.4 m), hence the location of the reinforcement bars need to be modified. Provide a lid for the drop hole, preferably connected to the slab with some kind of heavy-duty “hinges”. The lid can be made in wood (emergency situations), but preferably in concrete or metal that needs to be protected against corrosion (as the gasses within the pit are aggressive). A small piece of plastic pipe (diameter of at least 100 mm, preferably 150 mm and about 200 mm high) should be integrated in the slab's ventilation hole.
- Install the prefabricated slab with its lid on the lining / base of the organic waste pit, once it has settled for at least 3 days. To ensure a secure seating, the slab should be fixed to its lining / base (overlaps of at least 0.1 m) with a 10 mm thick mortar layer (T.B. 2.05).
- Place the plastic ventilation pipe over the small pipe integrated within the slab. The pipe should be at least 2.5 m long, with its outlet higher than the potential obstacles in the direct vicinity (e.g. buildings, trees). To prevent from being blown over during heavy winds, the ventilation pipe should be anchored to the fence of the waste zone or with cables to the ground. The outlet of the pipe should have a rain cap (Tee), being covered with a (preferably stainless steel) screen to avoid that vectors would enter inside the pit.
- Make a drainage channel around the organic waste pit to lead runoff water away, thus protecting its walls against erosion.

Operation

- Dispose of the organic waste into the pit immediately when it arrives at the waste zone. Use only one pit at the time. Make sure that the pits are always closed with the slab's lid.
- Rinse the organic waste bins with clean water, wash them with water and soap (detergent), rinse again, disinfect with a 0.1% chlorine solution (T.B. 2.20) and rinse a last time with clean water, before they go into circulation again.
- Close down the pit when the level of the organic waste is about 0.5 m underneath the slab. Put a thick layer of wood ash on top of the organic waste and top up with compacted soil if the pit is closed permanently. Do not use ash from burnt soft waste for this purpose. Most organic waste will decompose into harmless matter, so it is normally possible to empty a pit that has been closed down for at least two years. Be aware however that bones of amputated limbs will still be intact. The population could perceive the removal of these remainders as offensive. Take also special precautions to avoid injuries with sharps that have accidentally been discarded in the organic waste pit. A new permanent burial place should be found for the organic waste remainders, potentially a controlled tip (T.B. 5.03) or a sanitary landfill.

Remarks

- For very small health centres with only an occasional delivery (e.g. max. 3 per month) and no other medical interventions that generate organic waste, an organic waste pit isn't required. The placentas can be discarded in a simple pit or V.I.P. latrine.
- If the pit is dug in one time until the required depth and the soil is unstable, the vertical walls should be reinforced with removable struts during the excavation, or the hole should be made conical.
- The bottom of the pit should be at least 1.5 m above the highest possible water table. The latter can be estimated by verifying the water level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe in the ground, as deep as 1.5 m beneath the maximum pit depth. When pulled out, the rod or (the earth inside) the pipe should be dry. If not, the pit depth should be adapted accordingly. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level.
- Another construction method for an organic waste pit is the individual circular-shaped pit, which is often more difficult to excavate but less due to collapse because of its natural arching effect. This can be particularly interesting for emergency organic waste pits that won't be lined. When necessary, the circular pit can be reinforced with one or more perforated concrete rings (T.B. 2.06).
- If the subsoil is very rocky, the area flood prone or the water table high, the pit may partially be constructed in the ground and the remaining aboveground part in a very well compacted earth mound. A different technique (T.B. 3.12) will have to be used.
- If it rains a lot in the region, the lining / base can be made higher, for the pit to be less at risk of flooding.
- The calculated pit volume should include a free space above the waste of at least 0.50 m high. It isn't part of the effective pit volume, but will allow the pit to be closed properly once it's nearly full.
- In the very early stages of an emergency, layers of compacted soil or a temporary wooden slab can do to cover the organic waste, but must be replaced as soon as possible with a slab of more durable material (e.g. concrete). To be able to empty an organic waste pit safely, its slab should be completely removable, hence having a reasonable weight. It is therefore strongly recommended to use an adapted version of the standard size concrete VIP slab (adapted from T.B. 3.08).
- For a large pit with several slabs side-by-side, each one should have its own covered 0.3 m x 0.4 m drop hole, allowing an equal organic waste repartition over the pit. However, one ventilation pipe can be sufficient for the whole pit. All of the slabs have to be sealed to each other with mortar.
- The small plastic pipe in the ventilation hole should be flush to the bottom of the slab in order to avoid too many (burnable) gasses accumulating in the pit. To ensure a better anchorage, a clamp can be connected to the small pipe at the level where it will be mortared in the slab. To ensure a better evacuation of the gasses, the slab can be slightly tilted upwards towards the ventilation pipe.

- Only discard organic waste in the pit. Don't throw in any other kinds of waste, and certainly not sharps!
- Do not smoke when opening an organic waste pit because flammable gasses like methane might have accumulated underneath the slab!
- It is essential that the organic waste is covered immediately after disposal, to avoid bad odours and vectors (e.g. flies) being attracted to them.
- Adding lime to the organic waste pit can reduce drastically the smell, but might slow down the decomposition process. This might eventually result in the pit filling up faster. A better option is to introduce occasionally some wood ash, which does reduce the odours as well and might increase the decomposition rate. Besides, wood ash can often be obtained for free. However, do not use ash residues from the incinerator / volume reducer (incinerated / burnt soft waste).
- The slab and surroundings should be cleaned and disinfected regularly. Check frequently if the ventilation pipe isn't blocked. Remove all material that could obstruct the ventilation of the pit by pouring some water through the pipe. Check also if the screen is still intact and replace when necessary.
- The operator (waste manager) should receive intensive training and a complete set of protective clothing, which should always be worn during operation and maintenance (T.B. 6.10).
- If an organic waste pit is emptied (at least two years after it has been closed down), all its slabs should be removed to permit easy access and safe working conditions. Once all the slabs are removed, wait some time before entering into the pit to evacuate all hazardous gasses.
- During works within a used organic waste pit, make sure that the person inside has a strong rope around his waist, which permits colleagues standing at the side of the pit to lift him out if something goes wrong.

T.B. 6.09 Waste zone

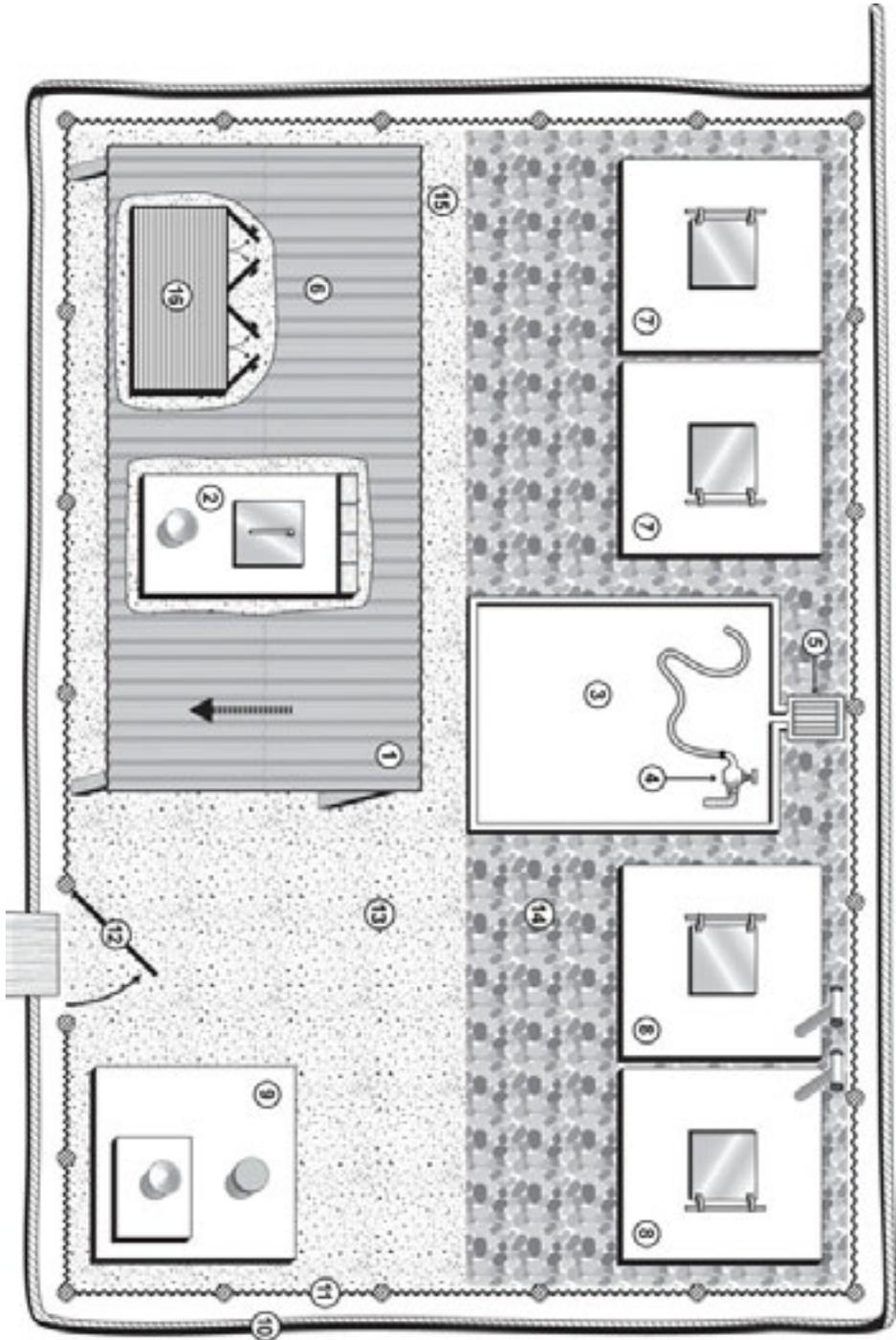
The waste zone is a special area within the compound of the health structure where all types of medical waste can be disposed of. This zone concentrates the different treatment / final disposal facilities to avoid that the contamination is spread over a large area. It also has the advantage of providing an “ergonomic” working environment for the operator being responsible of the area (waste manager).

Site selection

Choose a site for the waste zone that should ideally correspond to the following expectations:

- Located within the compound of the health structure.
- Away from groundwater points and preferably downhill from them to avoid direct contamination (minimum distance from groundwater points > 30 m and > 50 m when organic waste pits are present).
- Not liable to flooding.
- Water table stays rather low, even during the rainy season.
- Downwind of the health structure’s buildings and of the surrounding dwellings (for dominant winds).
- Easily accessible (even by truck for big infrastructures) to bring in waste and combustibles or to evacuate waste residues when emptying the residues or organic waste pits.
- Easy to drain runoff water away.
- Enough space available (for a possible extension).

Key	Input
1. Waste bins’ temporary storage place (under roof)	- Detailed plans (of different facilities)
2. Incinerator / volume reducer	- Experienced labour
3. Washing area (concrete slab with a protective kerb)	- Construction material and tools
4. Water supply	
5. Grid leading to a grease trap followed by an infiltration system / sewer	
6. Roof (with its slope indicated by the arrow)	
7. Residues (ash) pits	
8. Organic waste pits	
9. Sharps pit (with potentially a safety box reducer)	
10. Runoff water drains (preferably cemented)	
11. Fence	
12. Door (with padlock)	
13. Concrete floor (for chronic emergencies and stabilised situations facilities)	
14. Gravel (can be replaced by concrete for a cleaner / long-lasting waste zone)	
15. Parking place for a possible pushcart	
16. Closed storage space for tools and/or wood (used to start the incinerator / volume reducer)	



Remarks

- The type of facilities that are needed within the waste zone and their capacity depend on the types and amounts of wastes that are generated. The amounts of wastes are depending on the type of the health structure itself (e.g. OPD, IPD, hospital), its activities (e.g. operating theatre, maternity, laboratory) and its size, and also on the number of patients that are “passing by” every day (e.g. an organic waste pit is often not necessary in small structures or camp situations). It is important however to foresee enough space, as new pits might have to be dug once the old ones are nearly full.
- For emergencies, a simple waste zone can be made with temporary facilities (a temporary volume reducer, an emergency sharps pit made out of a drum, temporary ash and organic pits, and a washing area). Although temporary, the lay out of the waste zone must be respected to facilitate the work of the waste manager. In case the temporary health structure is closed, it is advised to remove the emergency sharps pits and to bury them in a safe area after having been encapsulated (T.B. 6.02).
- In case the construction of the complete waste zone would take long, a temporary waste zone with acute emergency facilities should be made as a first step, even for chronic emergencies and stabilised situations. This will enable to start immediately with correct medical waste management (T.B. 1.08), certainly if the staff has already been trained in segregating the waste and the use of the waste zone facilities.
- The site must be completely fenced and have a runoff water drain system.
- A roof has to be foreseen for the incinerator / (temporary) volume reducer(s) and for the temporary storage area for the soft waste, to avoid that it gets wet (and thus becomes more difficult to burn). It is also recommended to construct a roof over the potential safety box reducer, although that a protective hull (made with bricks or metallic sheets) can already be sufficient.
- The residues (ash) pit and the organic waste pit come preferably in pair and can potentially be reused. It's suggested not to put a complete concrete floor around the ash and organic waste pits, to be able to construct additional ones within the same waste zone when needed. Gravel around the pits is essential however as it will avoid that the waste zone turns into a mud pool.
- A washing area is essential for disinfecting, rinsing and cleaning the empty waste containers. Water supply, chlorine solutions and soap are essential for the washing area.
- A grease trap and infiltration system (T.B. 4.04, 4.06, 4.07 and 4.08) are necessary for the washing area.
- The waste zone and all reusable containers need to be inspected regularly and replaced when necessary.
- Only the responsible of the waste zone (waste manager) should have access to this site. In situations where the cleaning staff would do the waste collection and transport towards the waste zone, it can be interesting to leave an opening in its fence where the containers can be shifted through without having to enter the area.

T.B. 6.10 Protective clothing and equipment

Protective clothing for the maintenance staff is an essential part in conducting safe medical waste management. A good outfit might also raise to some extent the self-esteem of the maintenance staff as they are all too often forgotten. Good equipment and tools will also render the workload easier to bear.

Implementation

The main objective of protective clothing is to reduce the physical harm risk for the staff during their potentially dangerous activities. The protective clothing will have to be adapted according to the kind of activities performed by the staff. If the cleaners have to work with dangerous goods (e.g. highly concentrated chlorine solutions), a plastic apron, rubber gloves and goggles are essential besides the standard overall. The waste manager should have the same protective clothing as the cleaners, including a respirator, a face shield, heavy duty boots and preferably armoured gloves when he operates the incinerator. A poncho / rain coat and rubber boots come in handy during the rainy season for those staff working outside.

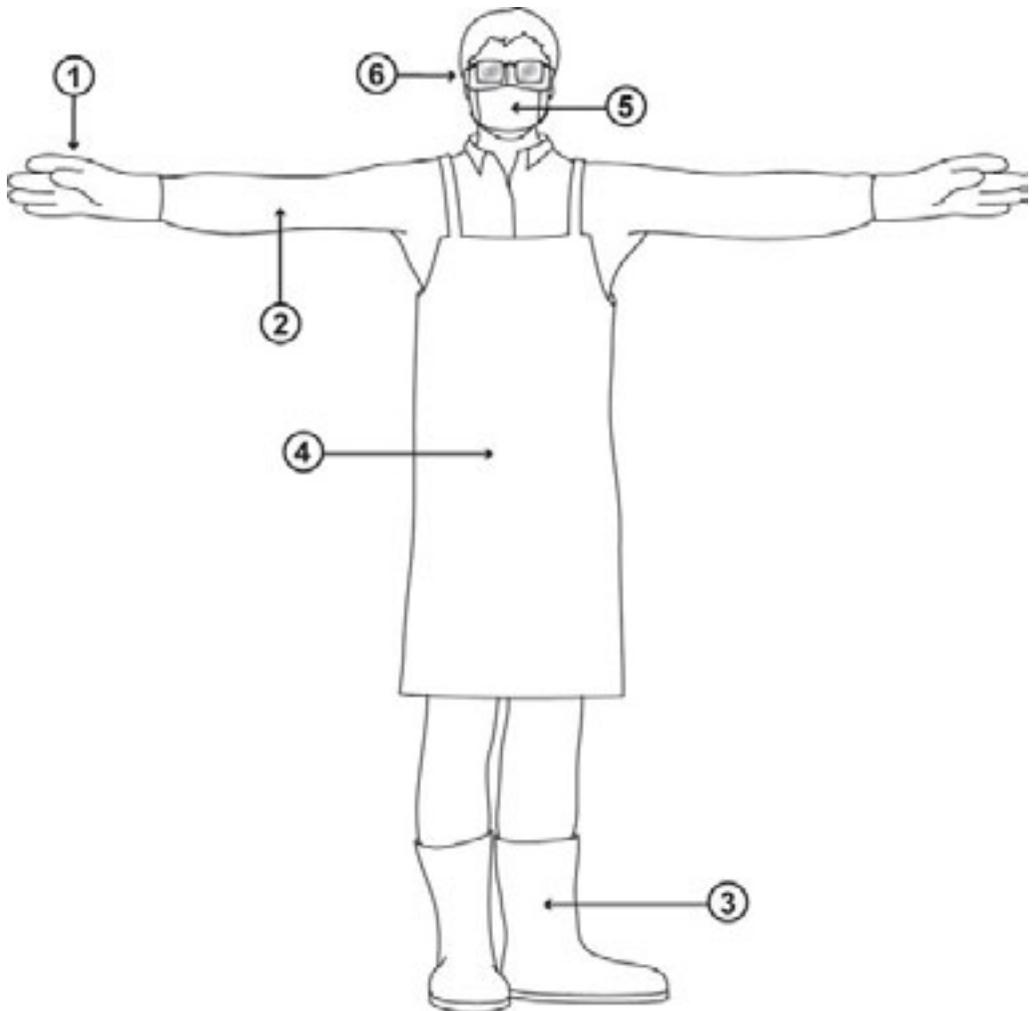
Besides the protective clothing, the staff should also receive correct equipment. This equipment should not only ease the work of the staff but also render it safer. Correct equipment includes amongst others:

- brooms,
- swaps,
- disinfectants,
- good waste bins (right size and colour) with well fitting lids,
- gardening tools,
- cart / trolley adapted to transport all the waste bins / sharps containers to the waste zone,
- soap to wash their hands and the waste containers.

Finally, the staff should be trained in using the equipment, the material (specially the use of disinfectants or other chemical products) and all the facilities correctly. Safety should be an important issue in the training package.

Remarks

- Make sure that the staff wears the protective clothing during work.
- Make sure that the staff washes their hands after having taken off their protective clothing.
- In big health structures (e.g. hospitals), a washing facility with shower should be foreseen for the staff, allowing them to take a shower before leaving (T.B. 4.01).
- The staff should be responsible for their designated protective clothing and equipment. If old gear is torn, it should be brought in to receive a new set.
- The working gear should preferably stay at the health structure, certainly during epidemics as they might be contaminated. Therefore, a changing place and a locker have to be foreseen.
- The working clothes will have to be washed regularly. If a laundry facility is part of the health structure, the clothes can be integrated in this circuit. If a laundry facility is not available, other arrangements will have to be made.
- Besides the protective clothing, it is strongly advised to vaccinate all the staff coming potentially in contact with medical waste against Hepatitis B and Tetanus.
- The staff should be informed that all (work related) accidents must be reported and that a medical follow-up is available to reduce the risk of the accident related infection.



Key

1. Heavy-duty (thick / armoured) gloves / rubber household gloves (when working with chlorine)
2. Overall or long sleeve shirt and working trousers
3. Good boots with strong soles (heavy duty shoes)
4. Apron
5. Respirator (when working with volume reducer / incinerator)
6. Face shield or goggles (when working with chlorine and/or a volume reducer / incinerator).

Vector Control

Narrative

Technical briefs

- T.B. 7.01 Mosquitoes
- T.B. 7.02 Flies (non biting)
- T.B. 7.03 Sandflies
- T.B. 7.04 Fleas
- T.B. 7.05 Lice
- T.B. 7.06 Rodents
- T.B. 7.07 Mites
- T.B. 7.08 Bedbugs
- T.B. 7.09 Cockroaches
- T.B. 7.10 Characteristics of public health pesticides
- T.B. 7.11 Understanding pesticides labels
- T.B. 7.12 Safe packaging, transport, storage and disposal of pesticides
- T.B. 7.13 Safe use of public health pesticides
- T.B. 7.14 Insecticide residual sprayer
- T.B. 7.15 Insecticide Residual Spraying campaign
- T.B. 7.16 Long-lasting insecticidal Nets (LN's)
- T.B. 7.17 Impregnation of nets, clothing and curtains
- T.B. 7.18 Insecticidal dusting
- T.B. 7.19 Rodent control
- T.B. 7.20 Protective Clothing

Chapter 7



7.1 Why carry out vector control ?

In low-income countries, vector-borne diseases such as malaria, dengue, leishmaniasis and sleeping sickness are common and among the important causes of morbidity and mortality.

Reasons for increased risk of vector transmitted diseases include:

- refugees or displaced populations may lack immunity to a disease or a particular strain of the disease in the settlement area (e.g. malaria).
- refugees or displaced populations having fled through an area infested with certain vectors (e.g. sandflies transmitting leishmaniasis).
- refugees or displaced populations live in crowded and unsanitary conditions, that result in a sharp increase of vectors - this may be compounded by a lack of sufficient water for personal and domestic hygiene (e.g. body lice transmitting typhus).
- poor housing favours an increase in vectors exposure, and the spread of the associated communicable diseases.
- being located in an area which supports significant vector populations (e.g. mosquitoes in a swampy area).
- loss of livestock, eventually causing vectors to feed increasingly on humans.
- lack of food and adequate health services.

Health structures are generally crowded with weakened people and high densities of pathogens are met. Without general vector control measures, the risk of further infection of the patients, caretakers, and visitors increases dramatically (e.g. body lice transmitting typhus). In addition, if the prevalence of vector-borne diseases is low in the area, small scale vector control measures in health structures are particularly important since the health structure is likely to be the major source of pathogens.

7.2 What is vector control ?

7.2.1 Vectors in precarious situations

A vector carries and transmits infectious pathogens directly or indirectly from a reservoir (e.g. environment, animal, human) to another host either mechanically or through its bodily functions. Infection can occur via biting (e.g. malaria transmitting mosquitoes), via (skin) penetration (e.g. typhus transmitting lice) or the gastrointestinal tract (e.g. food contaminated by flies). It is important to distinguish between a nuisance, and a mechanical and/or biological vector spreading a communicable disease.

Nuisance

It is their presence in large numbers that defines a pest population as merely a nuisance (e.g. bedbugs) instead of a vector. Control methods are generally designed to reduce the pest population or reduce the pest-human contact.

Mechanical vectors

These vectors transmit pathogens by transporting them on their feet or mouthpart (e.g. housefly). In this way pathogens are spread from contaminated material (e.g. faeces) to human foodstuffs, drinks, faces or eyes. Mechanical vectors are usually only one of several transmission routes for a particular disease. Diarrhoeal diseases, for example, as well as being transmitted mechanically by vectors are also transmitted through poor hygiene and contaminated water. Control measures for mechanical vectors are designed to reduce their population, and/or the likelihood of disease transmission (e.g. covering food to prevent vector access).

Biological vectors

Biological vectors may be a serious threat to health, even when their numbers are relatively low. These vectors are by nature involved in the life-cycle of the pathogen, which must pass through the vector in order to mature. The pathogens are acquired from, and are transmitted to, a human or animal host when the vector takes a blood meal (e.g. plasmodium cells via mosquitoes). Control measures are

designed to reduce the likelihood of person-vector contact, reduce the risk of the vector population becoming infectious and reduce the survival rate of the vector (e.g. Long-lasting insecticidal Net).

Following groups of vectors are considered of main interest in precarious situations. The biology, public health significance, methods of detection and simple control measures for these groups are described in the respective technical briefs.

- | | | |
|----------------------------------|-----------------------|---------------------------|
| - Mosquitoes (T.B. 7.01) | - Fleas (T.B. 7.04) | - Mites (T.B. 7.07) |
| - Flies (non-biting) (T.B. 7.02) | - Lice (T.B. 7.05) | - Bedbugs (T.B. 7.08) |
| - Sand flies (T.B. 7.03) | - Rodents (T.B. 7.06) | - Cockroaches (T.B. 7.09) |

7.2.2 Vector control

Control of these vectors, through personal protection, environmental and/or chemical control has a documented impact on the reservoir and/or on the transmission of important disease pathogens. Knowledge of the biology of each vector is an essential condition of effective control measures. It is useless to try to combat body lice by treating head hair, or to try to control *Culex* larvae by treating clean standing water. It is vital to know how, where and when to act.

Nevertheless, it is possible to identify some principles common to all vector control programmes:

- Complete eradication is generally unattainable. The objective should be to keep the vector population below a level at which it poses a too great risk of an epidemic.
- The aim should be to make the local environment unfavourable for the development and survival of the vector.
- Vector control is generally more effective if it is focused on immature forms of the vector.

7.3 Where/When should vector control be implemented and by Who?

Appropriate vector control measures must be implemented in endemic zones and/or in epidemic-prone contexts, and/or when there is a high presence of the vector. They must always be implemented in camps and all types of health structures, from small health centres to large hospitals including disease-specific programmes (e.g. kala-azar, yellow-fever, HIV) and Therapeutic Feeding Centres. This as specified in the essential water and sanitation requirements (T.B. 1.08, 1.09).

Particular attention should be given to vector control:

- In prevention of epidemics where it should take place immediately following identifiable alarm signals for a specific epidemic area (e.g. migration of large number of non-immune persons into high transmission areas, abnormally heavy rain, flooding, high minimum temperature).
- In epidemic control where outbreak detection takes place in the early stages and vector control activities can be achieved sufficiently early to cut off the peak in transmission.
- In areas of known intense seasonal transmission (and associated high morbidity and mortality) where vector control activities just before the peak season can reduce transmission.

The control of a specific vector, in an open setting outside a health structure or refugee or displaced camp requires a deeper understanding of the vector biology and of its interaction with humans and the environment, as well as expertise in specific vector control measures. These guidelines do not have the scope to deal with such issues in sufficient detail.

Timing of the vector control activities depend on the context but the desired outcome is to achieve the required coverage before the start of the transmission and to maintain a residual effect for its duration. Timing can have significant operational implications where transmission is largely confined to one season. In areas where transmission is more or less constant throughout the year, the timing is less of an issue.

A big factor in the effectiveness of vector control activities is a clear allocation of responsibility, at both a strategic level and at implementation level. Where the aid-agency is working in health structures that are part of local or national health infrastructures, it is especially important to define ultimate

responsibility with a view to the future running of the vector control activities. Once an agreement of responsibilities is reached amongst all the involved counterparts, it should be formalised in writing. An important body, in terms of providing direction and feedback to any vector activities, is the hygiene / health committee which should be present in all health structures.

Implementation of the vector control measures should be managed by a suitably experienced technician. The execution of environmental vector control measures requires relatively little technical skills once the facilities are installed, and will typically be carried out by trained health structure cleaners, caretakers or grounds men. Avoid people with the following risk conditions when selecting staff to make up a chemical vector control team: pregnancy or lactating; alcoholism; history of liver or nerve disorder; heavy smoking; allergies or skin diseases. More subjective criteria are also important: like professional integrity, meticulous work and neatness and tidiness.

Chemical control measures involving pesticides and other toxic chemicals require expertise and should only be carried out by those who have received appropriate training on safe and effective procedures (T.B. 7.13). Even for apparently straightforward application of public health pesticides, a minimum of protective clothing is required (T.B. 7.20).

Each person is responsible for their own personal protection against disease transmitting vectors. The personal protection strategies are simple and can potentially be implemented individually. However they need to be supported by appropriate and simultaneous promotional activities. Otherwise, it may be difficult to persuade persons to protect themselves, especially when they are not greatly bothered by bites from the vectors present.

7.4 How to carry out effective vector control ?

7.4.1 Planning and organisation

As with all interventions, the project cycle of assessment, strategy planning, implementation, monitoring and evaluation should be followed when setting up a vector control intervention. The below comments highlight some specific key considerations related to the planning and organisation of vector control activities.

Assessment & analysis

Assessment should be based on the essential requirements, checklists and the accompanying guidelines on appropriate usage of vector control tools (T.B. 1.06, 1.08, 1.09).

Strategy planning

The vector control activities should be guided by national legislation and clear objectives that address the vector-related priority problems identified in the assessment and analysis. Common objectives of vector-control activities include: preventing or controlling outbreaks, stopping preventable deaths from vector-borne disease, minimising illness from vector-borne diseases or protecting the population subgroups with reduced immunity.

The objectives of the vector control activities can only be achieved with appropriate vector control measures addressing the context specific epidemiological situation and risk factors. Vector control may have no impact if it targets the wrong vector, uses inappropriate or ineffective methods, or targets the right vector at the wrong place and/or at the wrong time. The selected vector control measures should be appropriate for controlling the specific vector species, given its breeding, flight range and resting behaviour. Also, the measures should be simple to understand and apply. Where vector-borne diseases become a problem, using chemicals should always be regarded in combination with environmental sanitation and promotional activities.

When considering the use of chemical control measures it should be remembered that although public health pesticides are relatively safe, they can be toxic and dangerous to both living creatures and the environment if not used properly (T.B. 7.10, 7.11, 7.12 and 7.13). All vector control activities should be based on the national and international protocols. Certain vectors rapidly develop resistance to particular pesticides and the choice

of pesticide should take this into account. The decision to carry out a chemical control program and the choice of the pesticide should always be made in consultation with your technical referent.

Implementation

Staff training is very important in vector control interventions, particularly where chemical control measures are being used. Inappropriate usage and disposal of pesticides is the most common problem and has detrimental effects on people and the environment. Comprehensive training should be given to all staff on safe and correct usage of chemical control measures. All employees, patients of the health structure, as well as the whole camp population should be given information on both personal protection methods as well as their role in the general vector control activities.

Monitoring / Evaluation

Monitoring will ensure a vector-borne disease outbreak is detected early and will prevent any waste of resources on inappropriate control measures. Evaluation will measure the effectiveness and impact of the activities. Vector control requires close management of personnel to insure that work is carried out in accordance to pre-defined standards and strategies. Consistency of effort is very important in vector control (e.g. small lapses in sanitation activities like open disposal of food waste can result in a rodent or fly invasion within days). Therefore, the performance of staff involved in on-going sanitation / vector control activities should be continuously monitored and regularly evaluated. The details of intermittent vector control activities, such as insecticide residual spraying or impregnation of bednets, should be recorded in a specific logbook. Such records are essential to inform upon the appropriateness of future activities e.g. the timing to repeat insecticide residual spraying. Recorded information should include: why, what, where, when, who and how the particular activity was carried out. As well as monitoring the vector control activities themselves, attention should be paid to environmental factors external to the health structure or camp, which may affect the prevalence of vectors, and their associated diseases in the area. For instance, seasonal changes in climate, or a substantial influx of new beneficiaries may result in increased disease transmission by vectors.

It is essential for the vector control planners to work closely with the health care staff and those responsible for epidemiological assessment and monitoring.

It is important that clear case definitions are adopted and whenever possible laboratory confirmation of the initial suspected cases is sought. In addition to the routine health information system, there must be a standard procedure for immediately reporting vector-borne diseases with epidemic potential indicating the location of suspected cases. From the very onset, a map of the area should have been sketched showing where population clusters, suspected cases, and potential vector breeding sites are located. Because each vector species has a characteristic breeding and biting habit, they should be monitored using different vector-specific methods and indicators (T.B. 7.01 until 7.09).

Evaluation can be based on direct observation (e.g. proper use of LN, state of pit latrines, food preparations and refuse collection sites). It can also be more formal by re-assessing against the initial assessment and essential water and sanitation requirements (T.B. 1.06, 1.08, 1.09).

7.4.2 Vector control strategies

Different vector control strategies are presented here. Generally the most effective control of any vector will utilise a range of different activities which intervene in various aspects of the reservoir and transmission routes.

Environmental control

■ Site selection and planning

It is important to select a site that does not expose the patient, refugee or displaced population to excess risk for vector-borne diseases. Sometimes the choice of a site is limited by politics, security or other factors (T.B. 1.10).

■ Water management

Environmental control methods include avoiding the creation of breeding sites like pools of standing

water inside and outside (e.g. open water reservoirs, flower pots, bottles, old tyres, stagnant water and blocked drains) and removal of existing breeding sites (by filling or draining them). However, good local knowledge and entomological expertise are required to target the most productive breeding sites in the surrounding and to avoid wasting time and recourses on unimportant breeding sites.

■ Safe excreta disposal

Basic sanitary engineering measures should be taken whenever possible to reduce the opportunities of insect vectors breeding. Latrine design should minimize the access of vectors to reduce the opportunity for them to breed; e.g. use of lids, VIP latrines or water seal designs (Chapter 3).

■ Waste management

Waste collection and disposal points should be sealed from the environment (e.g. garbage bins with lids, waste pits with a lid, or covered daily with ashes / soil in acute emergencies) (Chapters 5 and 6).

■ General construction

Building design should minimize mechanically the access of vectors into the structure; e.g. insect screens, sealing of openings under doors, rodent baffles on drainpipes.

■ Removal of vegetation

Mowing or even burning of vegetation (control the risk of fire) in the vicinity of camp sites and buildings can be recommended to control mites and ticks. Piles of decaying grass clipping, compost heaps and other accumulations of rotting vegetable matter serve as good breeding places for flies. Nevertheless, there is no evidence that the widely advocated practice of cutting down grass and bush around houses in general reduces malaria transmission. Clearing of vegetation may however be effective in removing resting places for adult mosquitoes, promote the evaporation and drying up of small accumulations of water and make breeding sites more visible for control purposes.

Personal Protection

Personal protection methods may offer significant safety using simple, small and portable equipment against infection and vector nuisance. Methods include:

■ Personal hygiene and behaviour

Regular and complete personal hygiene (e.g. hand and face washing, washing of body and clothes with soap, food covers) will reduce the chance of disease transmission by flies or lice. Sufficient water is necessary for personal and domestic hygiene. This also requires the availability of sanitary facilities and the promotion of personal hygiene within the project team, health structures and/or camp population.

■ Protection by clothing

Clothing can be an effective physical barrier against several biting insects and can therefore reduce the risk of disease transmission. Effectiveness of protection will increase with the thickness of the material and the amount of skin covered. The impregnation of clothes with a repellent offers better protection and typically lasts for a few days. The impregnation of clothes with an appropriate insecticide is also an option and typically lasts for about 5 washes.

■ Repellents

Repellents can be either natural or chemical products to be used as protection against insects. They can be applied on the skin or clothes. Natural products are often country specific. Chemical products such as DEET® (NN diethyl 3 methylbenzamide) are usually more effective and longer lasting than natural products. They occur in a range of applications such as lotions, sprays and creams. Applied on the skin they usually offer protection for between 6 and 8 hours, limited by the sweating of the person. They do not offer the required protection for a person asleep throughout the night. Cutaneous use of DEET® does not provoke undesirable reactions with adults. Repetitive cutaneous use of DEET® is not recommended for pregnant women and young children (below 30 months). For them, it is more appropriate to use the repellent on their clothing instead.

■ Coils

Coils can be used as a quick and easy way to neutralise insects in rooms or enclosed areas where no electricity is available. Burning coils vaporise an insecticide into the air and this has, where ventilation is limited, a knockdown effect on mosquitoes. Public health pesticides present in coils are formulated at a relative low dosage.

The quality of coils can vary greatly and some are completely ineffective. In some countries, coils are formulated with organochloride compounds which give rise to serious health concerns. Still the most commonly used active ingredient belongs to the group of quick knock-down pyrethroid. In confined areas such as a closed tent or a non-ventilated room, the smoke may cause irritation to the eyes and lungs. Depending on the active ingredient, burning coils may also have a repellent effect on mosquitoes in open veranda's. If the coils are used outdoors it is important that they are upwind of the people to be protected.

The whole period of burning normally lasts between 6 and 8 hours and one coil can be used for a room of approximately 35 m³. The coils should be lit just before the mosquitoes become active. To increase efficiency, convenience and safety, coils should be burnt in special holders.

■ Electric vaporizer systems

Electric vaporizer systems are products requiring an electrical heating device to evaporate an insecticide from a base, which may be composed of any suitable material and which is referred to as "refill". The heater and refill are a unit and must be used together. These systems have been designed mainly for the control of mosquitoes and work only with a reliable electric power supply. The heating devices should provide a sufficient duration of operation and should not be affected by tropical climates, such as heat combined with high relative humidity. The active ingredients used in these systems belong to the natural pyrethrins and quick knock-down pyrethroids.

■ Aerosols

Aerosol sprays can be used when a room or closed area needs to be cleared of flying or crawling insects. Flying Insect Killer aerosols (FIK) use a short lasting insecticide easily dispersed in space. The active ingredients in FIK are usually from the pyrethroid family. In FIK, a combination of a killing agent and a knockdown agent is very common. The knockdown effect of the aerosols will eliminate most flying insects within 15 minutes. Their residual effect is very limited which means that a cleared room can be reinvaded by insects about 20 minutes after treatment. It also means that there is little risk of toxic residues in the treated area. After spraying, the room must be left immediately and stay close for about 20 minutes. The windows must be opened to ventilate after re-entry.

Crawling Insect Killer (CIK) aerosols however exhibit excellent residual effect due to their adherence to surfaces. Those designed to be applied directly onto insects such as cockroaches, silverfish, bugs and ants have also very good knockdown effect. If applied as surface spray, the residual effect may last several weeks (4 to 8 or even up to 12 weeks) depending on the physical properties of the surface, the active ingredient applied and its formulation. Most aerosols contain flammable substances and they should not be directed on fires or smouldering objects (do not smoke, disconnect electric equipment while spraying), and be protected from direct sunlight and temperatures exceeding 50 °C. Follow carefully the application instructions and safety measures indicated on the spray cans. Empty pressurized spray cans should be disposed of in an enclosed sharp pit (if few in number, T.B. 6.02) or by encapsulation if more numerous.

■ Long-lasting insecticidal Nets (LN; T.B. 7.16)

Insecticide-treated nets are one of the major ways to control malaria and they are accepted worldwide by communities affected by malaria. Their correct utilisation reduces the survival chance of the vector and interrupts malaria transmission.

Apart from their killing effect, nets will also avoid mosquito feeding, hence reducing the reproductive potential of vectors that feed on human blood. Insecticide treated nets have the same disabling effect on

other biting insect vectors like lice, fleas and sandflies. They also protect against spiders and cockroaches. Within a health structure they prevent the spread of vector borne diseases, by isolating patients and limiting thus further transmission of the pathogen; this is especially important in the context of malaria, yellow fever, dengue and leishmaniasis.

Traditional insecticide-treated nets require re-impregnation (T.B. 7.17) every six to twelve months which is difficult to implement. The best results can be obtained with Long-lasting insecticidal Nets (LN), which retain their insecticidal properties for two to six years, the life span of the net, thus making re-treatment unnecessary (T.B. 7.16). These LN would be expected to retain chemical activity for at least 20 standard washes as defined by WHO. The use of LN is strongly recommended over the use of nets that require re-impregnation.

A requirement for successful use of insecticide-treated nets is that the malaria transmitting vector feeds at a time and place when people are using the LN. LN's will only have an impact on malaria transmission if they are properly used and maintained, hence the importance of appropriate and simultaneous promotional activities. The use and acceptance of LN depend on a range of social and cultural factors that should be identified and taken into consideration prior to distribution. The identification of these social and cultural factors is less relevant when implementing LN in a health structure but occasional evaluation of their actual use by sleeping patients is recommendable.

■ Other insecticide-treated materials (T.B. 7.17)

Blankets and shelter material are often distributed as part of the emergency response and these materials may constitute the only surfaces suitable or readily available for insecticide treatment. In areas where mosquitoes bite early in the evening, before patients go to sleep under nets, use of insecticide-treated curtains over openings such as windows, doors and eave gaps may provide protection.

Chemical control

■ Insecticide Residual Spraying (IRS; T.B. 7.14, 7.15)

IRS is widely used for vector control, especially against mosquitoes, triatomine bugs (vector of Chagas disease) and sandflies. Its objective is to ensure the safe and correct application of a residual insecticide dose to surfaces on which vectors may rest, usually ceilings, inside surfaces of tents and walls and the lower surfaces of large furniture. It is an effective manner of interrupting malaria transmission through killing adult female mosquitoes after feeding but before they can transmit the infection to another person. As such, it is not useful for the control of mosquitoes which tend to rest outdoors. However, it may be effective against outdoor biting vectors which enter houses for resting after feeding.

IRS is only effective if adequate coverage is achieved and if the insecticide is correctly applied. The selection of the insecticide has to take into account the susceptibility of local vectors and duration of the residual effect in relation with the length of the transmission season. Prior to implement IRS, verify these issues with your technical referent.

■ Insecticide zoo-prophylaxis

Insecticide zoo-prophylaxis could be used in settings where vectors bite domestic animals as well as humans. Rather than being applied to houses, the insecticide is applied to the hair and skin of domestic livestock, such as cattle, goats and sheep, using a sponge or animal dip. A specific dose can also be applied between the shoulder blades from where it spreads over the skin. Trials of this method have shown its effect on malaria and trypanosomiasis transmission reduction.

■ Insecticidal dusting (T.B. 7.18)

An insecticidal dust consists of talcum powder, or another inert carrier powder, mixed with insecticides. In health structures, insecticidal dusting can be applied on rodent footpaths and habitats. When the rats groom themselves, the dust spreads on their fur, thus killing their fleas.

Prior to dusting people against lice, verify with your technical referent the insecticide to be used.

■ Rodenticides (T.B. 7.19)

An important method to reduce rats and mice related health risks is poisoning them with rodenticides. Complete eradication remains very difficult as only a limited area can be targeted with rodenticides. The control campaign should be accompanied by promotional activities on proper household hygiene behaviour. Use chronic or slow acting poison instead of acute poison to limit the risk of accidental poisoning of humans and non-targeted animals.

■ Larviciding

Larval control is most practicable where the vector breeding sites are limited in number and relatively permanent in time. It requires the ability to locate and map out a very large proportion of the breeding sites within vector flight range of the community which it is required to protect. It is complex, requires expertise, but can significantly affect vector densities. In areas where it is an acceptable option, larval control must be carried out thoroughly to have an impact.

The most commonly used larvicide is the temephos®, an organophosphate which is effective and safe in drinking and bathing water. It is to be applied at very low concentrations. Some living organisms, such as bacteria (e.g. *Bacillus Thuringiensis israeli*) can also be used against vector larvae as they contain toxins against larvae.

■ Space spraying

A space spray is a liquid insecticide, dispersed into the air in the form of millions of tiny droplets. It remains only effective while the droplets remain airborne. The aim of space spraying is usually to rapidly reduce populations of flying insects to reduce or interrupt temporarily the transmission cycle of insect borne diseases. Mosquitoes, houseflies, and other biting flies may be targeted by space spraying. Nevertheless space spraying is complex, requires expertise and only has a temporary effect with little or no residual effect. As such space treatments must be considered in conjunction with other control methods where possible.

7.4.3 Vector control strategies in malaria transmission

Malaria is a most important vector-borne disease worldwide in terms of morbidity and mortality. It is considered to be one of the five top causes of child mortality in the acute phase of a majority of refugee emergencies. All malaria is transmitted by the *Anopheles* mosquitoes.

Mosquitoes behaviour

Several aspects of mosquitoes behaviour are relevant when determining a vector control strategy:

■ **Feeding time and location:** most *Anopheles* feed at night but each species feeds at a particular time of night. Some mosquitoes prefer to feed inside houses and others outside. In Africa, it can be assumed (until proved otherwise) that malaria vectors bite at night and rest indoors. Control measures can thus be taken accordingly.

■ **Host preference:** some mosquito species prefer to feed on humans and others on animals; several species feed partly on humans and partly on animals. Species that have a strong preference for feeding on humans tend to be the most dangerous vectors because they are the most likely to transmit malaria pathogens.

■ **Resting location:** after feeding, a female mosquito needs somewhere to rest while digesting the blood meal and developing its eggs. Some species rest inside, while others go and find places outdoors. IRS is not useful for the control of mosquitoes which tend to rest outdoors. However, it may be effective against outdoor biting mosquitoes which enter houses for resting after feeding.

■ **Choice of egg laying site:** *Anopheles* mosquitoes have different preferences for breeding sites or larval habitats, and lay their eggs in a wide variety of water bodies. Individual species tend to choose a narrow range of egg laying sites.

■ **Flight range:** most *Anopheles* mosquitoes do not fly more than 3 km from where they begin their lives. Malaria risk can be reduced by installing health structures or refugee or displaced camps further than 3 km from breeding sites.

Malaria control strategies

Malaria control strategies that kill and reduce the density of the vector (e.g. larviciding, space spraying) or that reduce the intensity of the contact between vector and person (e.g. non-impregnated nets, screening houses, repellents, protective clothing) have a lower impact than strategies reducing the survival chance of the vector (e.g. IRS, LN, zoo-prophylaxis).

Adequate coverage of human habitations with IRS and LN reduces the survival chance of mosquitoes that enter dwellings to seek a blood meal and shortens their average lifespan. This reduces the proportion of mosquitoes living long enough for the malaria cycle to be completed and thus becoming infective. A decreased proportion of old malaria infective mosquitoes in the total female mosquito population considerably reduces malaria transmission.

As such, and where possible, the malaria control methods of choice are IRS within the inside surface of houses or tents (T.B. 7.14, 7.15) and LN distribution (T.B. 7.17). Both are about equally effective against mosquito species that bite at night and rest indoors like it is the case, unless proven otherwise, in Africa for malaria vectors (*Anopheles*).

IRS and/or LN

The final choice to implement IRS, and/or a distribution of LN can only be made after studying both options in detail in the given context. There is no “standard” best approach for a given situation as the final decision to implement either IRS and/or distribute LN will depend on many factors, and advantages and disadvantages will have to be weighed to each other (see hereunder).

IRS		LN	
<u>Advantage</u>	<u>Disadvantage</u>	<u>Advantage</u>	<u>Disadvantage</u>
Can not be looted, stolen or sold	Can not be moved if the population is displaced	Can be transported by beneficiaries if they have to move.	Can be looted, stolen or sold
Protect the whole family and does not require any significant behaviour change.			-Might be improperly or not used at all -Space in the shelter might be insufficient to put up enough nets to protect the whole family
A high coverage is easy to obtain in a short time frame.	To be effective, more than 80% of the shelters need to be sprayed so it cannot be targeted specifically to vulnerable groups.	The personal protection provided allows deployment in a progressive way, starting with low population coverage. Distribution can also be targeted to vulnerable groups	-A high coverage is difficult to obtain. -Low retention rates in camps where families choose to sell the net to increase family food intake.
	Will only remain effective for 3-6 months, so it needs to be repeated	Can remain effective for 3 to 5 years	
Often quick to implement, especially in camp settings and emergencies.			Net distribution can be complex to organise. It will require community participation and promotional activities.
In areas where malaria transmission is confined (largely) to one season, one IRS is needed per year	In areas where malaria transmission is constant, IRS needs to be repeated every three to six months.	Only one distribution each 3-5 years	
Low start-up cost			Higher start-up cost but long impact (3-5 years)

In acute emergencies, IRS is often used initially, especially when LN are not readily available on the ground. It is quick to deliver and high coverage is easy to obtain at relatively low cost. When IRS needs to be continued for many years, there may be an attrition of people's acceptance to spraying. In contrast, LN's are more suitable for progressive introduction and incorporation into population habits.

7.5 Further reading

Médecins Sans Frontières

Clinical Guidelines,
MSF, 2007

L. Lacarin, R. Reed,

Emergency Vector Control Using Chemicals
WEDC, Loughborough University, 1999.

J. Rozendaal.

Vector Control: Methods for Use by Individuals and Communities
World Health Organisation (Geneva), 1997.

M. Thomson.

Disease Prevention through Vector Control: Guidelines for Relief Organisations
Oxfam Publication (Oxford), 1995.

T.B. 7.01 Mosquitoes

Mosquitoes are a large arthropod group found around the world. The most important genera in terms of disease transmission are the *Anopheles*, *Aedes* and *Culex*. Their life cycle is closely linked with water.

Biology

Mosquitoes have four distinct stages in their life cycle: egg, larva, pupa and adult. The first three phases are aquatic. Under good conditions, the entire period from egg to adult takes about 7-13 days. Males only feed on flowers nectar. The females usually mate only once but produce eggs throughout their life. Each blood-meal is often followed by laying eggs. Their adult lifespan varies from one to several weeks. Depending on the species, female mosquitoes are able to lay between 30 to 300 eggs at a time. For their blood-meal, the female mosquitoes are attracted by odour (e.g. smelly feet), carbon dioxide and body heat.

- Most *Anopheles* mosquitoes breed in non-polluted water sources e.g. pools, quiet places in slow-running streams, rice fields, leaf axils of certain plants and puddles of rain water. Eggs are laid individually and float on the water's surface. Only older females (2 weeks or more) can transmit malaria. They usually fly, noiseless, up to 3 km from their breeding site but have been found to be carried by the wind up to 30 km from their breeding site.
- *Aedes (aegypti)* mosquitoes mainly breed in relatively clean water in the domestic environment; e.g. small water storage tanks inside / outside houses, roof gutters, leaf axils, bamboo stumps and temporary containers (e.g. used car tyres, tin cans). Single eggs are laid close to the water surface.
- *Culex* mosquitoes prefer breeding in water polluted with organic material like refuse, excreta or rotting plants (e.g. in soak away pits, pit latrines, septic tanks, blocked drains, canals). Eggs are laid in rafts of over 100 and float on the water's surface.

Health Importance

- *Anopheles*: transmits malaria and filariasis (Bancroftian and Brugian).
- *Aedes*: transmits yellow fever, dengue, filariasis (Bancroftian) and other viral diseases.
- *Culex*: transmits filariasis (Bancroftian), Japanese encephalitis and other viral diseases.

Detection

- In Africa, it can be assumed until proven otherwise that malaria transmitting *Anopheles* species bite essentially at night and rest indoors; control measures can be taken accordingly. They are often found resting inside houses in dark corners of rooms / latrines / showers. *Anopheles* are most easily monitored in their adult form through the following methods: morning indoor collection of mosquitoes resting on the wall using a simple tube; morning indoor pyrethrum spraying (e.g. with aerosol spray) and collection of dead mosquitoes on white sheets spread on the ground (also under the beds and furniture); night time capture on human bait or alternatively with battery powered light trap collections.
- *Aedes* species bite mainly outdoors, in the morning and early evening during cocktail hour (dusk). *Aedes* are also better monitored through larval surveys of domestic water containers. For example, in larval surveys for yellow fever and dengue control, the results are expressed in terms of standard indices of *Aedes aegypti* (e.g. Breteau Index) to predict the chances of disease transmission in a population.
- The most common *Culex* species bite during the night, indoors and outdoors. *Culex* are better monitored (and controlled) through larval surveys of drains loaded with organic material and pit latrines because they often produce enormous numbers of eggs that can easily be detected.

Control

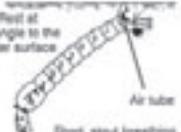
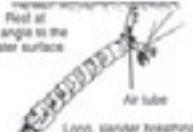
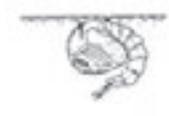
Mosquitoes control activities should systematically be integrated, as per essential requirements (T.B. 1.08, 1.09), in endemic zones or during outbreaks of malaria, yellow fever, dengue, lymphatic filariasis and/or when there is a high presence of the vector. Personal protection methods may additionally offer significant protection against infection and mosquito nuisance.

Contact your technical referent to obtain information about mosquito behaviour as several aspects of it are relevant when determining a vector control strategy (section 7.2.2).

- Strategies aiming to reduce the survival chances of *Anopheles* like the use of Long lasting insecticidal Nets (T.B. 7.16) or Insecticide Residual Spraying (T.B. 7.14, 7.15) are the most successful for reducing malaria transmission (more detailed control measures are presented in section 7.2.3).
- *Aedes* is often associated with human dwellings where its breeding site can be any open container of water. Control measures aim at getting rid of these types of sites, or at protecting them (e.g. a cover, mosquito netting). Large containers of water should be frequently, at least once a week, emptied.
- Control measures of *Culex* aim to eliminate bodies of stagnant water loaded with organic matter (e.g. latrines), or if not, then to eliminate surface vegetation in stagnant water and verify that these water bodies are at least 1.2 m deep.

Key

Criteria for recognition of the different mosquitoes genera

<i>Anopheles</i>	<i>Aedes</i>	<i>Culex</i>
<p>Eggs</p>  <p>Laid singly</p> <p>Has foets</p>	<p>Eggs</p>  <p>Laid singly</p> <p>No foets</p>	<p>Eggs</p>  <p>Laid in rafts</p> <p>No foets</p>
<p>Larvae</p>  <p>Rest parallel to water surface</p> <p>Rudimentary breathing tube</p>	<p>Larvae</p>  <p>Rest at an angle to the water surface</p> <p>Air tube</p> <p>Short, stout breathing tube with one pair of hair tufts</p>	<p>Larvae</p>  <p>Rest at an angle to the water surface</p> <p>Air tube</p> <p>Long, slender breathing tube with several pairs of hair tufts</p>
<p>Pupae (differ only slightly)</p> 		
<p>Adult</p>  <p>Proboscis and body in same straight line</p>  <p>Maxillary palps</p> <p>Maxillary palps as long as proboscis</p>  <p>Wings spotted</p>	<p>Proboscis and body at an angle to one another</p>   <p>Maxillary palps</p> <p>Maxillary palps shorter than proboscis</p>  <p>Wings generally uniform</p> <p>Tip of female abdomen usually pointed</p>	<p>Proboscis and body at an angle to one another</p>   <p>Maxillary palps</p> <p>Maxillary palps shorter than proboscis</p>  <p>Wings generally uniform</p> <p>Tip of female abdomen usually blunt</p>

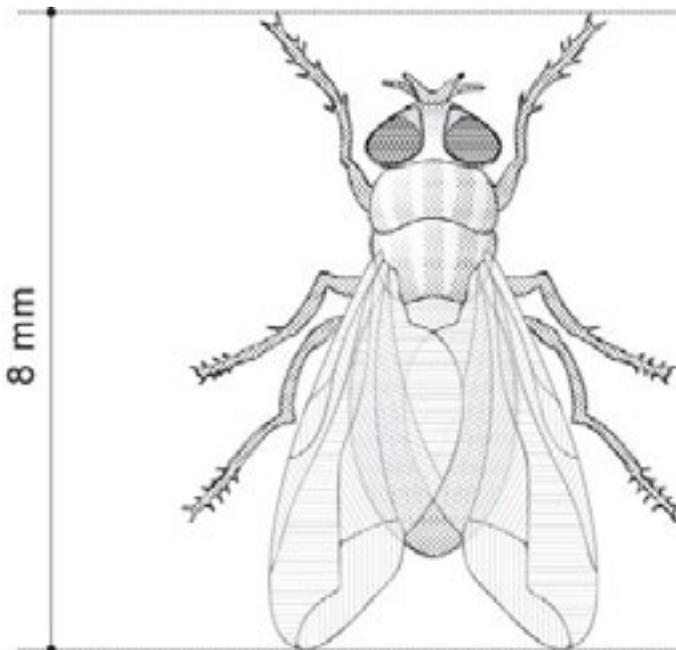
T.B. 7.02 Flies (non biting)

Domestic flies are widespread across the world and they are the insects most closely associated with humans. The housefly, the face fly and the blowfly are considered to be of main health importance, because they carry pathogens from human to human or from faeces to food.

Biology

The life cycle of the fly consists of four stages: egg, maggot (larva), pupa and adult. A single female housefly can lay up to 2000 eggs a month. Eggs are deposited in various habitats, especially in garbage and human and animal wastes. Depending on the temperature, it takes from one to six weeks for the egg to develop into an adult. Adult flies have a life span of three weeks to three months, depending on the climate and the species of concern. Flies feed on all kinds of waste, sweat and excreta (human or animal).

- The housefly breeds in organic domestic waste in urban areas and tends to breed in animal excrement in rural areas. Contrary to popular belief, houseflies do not lay their eggs in latrines.
- The face fly breeds predominantly on human faeces on the soil surface, but not in covered pit latrines. They are known to feed on the secretion produced by eyes of people, especially children, and hence they are an agent in the transmission of the eye disease trachoma.
- The blowfly has a strong preference for breeding in pit latrines, decomposing meat, garbage and animal excrement. Simple pit latrines in refugee camps often provide an ideal breeding site. Blow flies rarely enter houses, but are very active in market places. They are easily recognized by their shiny green colour.



Housefly

Health Importance

The non-biting flies of health importance usually hover around food, carrion, garbage, and human and animal waste. When they land, they may either transfer or carry pathogens that attach on their legs and other parts of their bodies. These pathogens may then be mechanically transferred to humans and/or animals. Even though they can also be transmitted via fly faeces, pathogens do not undergo biological transformation in the flies. Pathogens that are carried by flies are known to be responsible for enteric infections (e.g. dysentery, diarrhoea, typhoid and certain helminth infections), eye infections (e.g. trachoma, epidemic conjunctivitis), poliomyelitis and some skin infections (e.g. leprosy, mycoses).

Flies are usually not associated with cholera. A larger infectious dose of cholera bacteria is required for direct cholera transmission than the body surface of the fly allows to carry. However, once a small number of cholera bacteria is deposited on non-covered food it can incubate and multiply until the infective dose is reached.

Detection

It is more difficult to monitor non-biting fly populations than mosquito populations. Rather than counting the number of flies collected over time per sticky trap, monitoring of fly populations is best carried out as part of larval control and sanitation inspections, especially around feeding centres, hospitals, latrines, and refuse disposal sites.

Control Methods

Fly control activities should systematically be integrated, as per essential requirements (T.B. 1.08, 1.09), in endemic zones or during outbreaks of enteric and eye infections, and/or when there is a high presence of the vector.

Larval sites (the places where eggs are laid and where the larvae develop) are very often a product of human activity. The basic principle of all control measures should be to reduce or remove these sites, or to prevent access to it by flies. Without these environmental hygiene measures, all control efforts are in vain.

Personal protection methods (e.g. Long-lasting insecticidal Nets (LN), T.B. 7.16) may offer significant protection against infection and fly nuisance.

Flies should preferably be controlled by improving environmental sanitation and hygienic conditions:

- Reduce or eliminate fly breeding sites (e.g. dead animals and waste from slaughter houses should correctly be disposed of as soon as possible).
- Reduce sources that attract flies from other areas (e.g. limit open defecation, cleaning of animal excreta in cattle raising areas, make smooth floors in feeding centres (smoothed cement or plastic sheeting) to enable cleaning of spilled food).
- Prevent contact between flies and disease causing germs (e.g. isolate patients under LN, make covered refuse containers available in laboratories and health centres).
- Protect food, eating utensils and people from contact with flies (e.g. promotional messages).
- Ensure good removal and disposal of wastewater, particularly at washing areas for clothes and cooking utensils.
- Add ashes to latrine pits after each defecation, or at least every morning and night, to reduce the contact between flies and excreta.

Recourse to chemical intervention should be avoided as much as possible, because of the rapidity of appearance of resistant strains which render this option costly and ineffective.

In the case of massive infestation or when the presence of flies creates a concrete risk of increased spread of pathogen, or when an operating theatre or treatment room must be protected, the use of larvicides and adulticides should be considered, but always in tandem with environmental measures.

An option to destruct larvae is the use of larvicides on larval sites (e.g. in case of massive infestation by larvae of a defecation trench or latrine). To destruct adults, treatment with a residual effect should

be done on the surfaces where flies land and rest at night. These places may differ according to the species and the climate. In general, they are external surfaces of buildings (in hot countries), trees, fences, dustbins, animal shelters. Spraying of the interior walls of the latrines is also an interesting option.

In certain places (e.g. operating theatre, dispensary, kitchen), strips of gauze or cotton impregnated with insecticide (T.B. 7.17) may be used. Use 1 m length of impregnated strip per m² of ground surface area to be protected and renew the impregnation every 2 months. This in addition to the recommended Insecticide Residual Spraying (T.B. 7.15).

Remarks

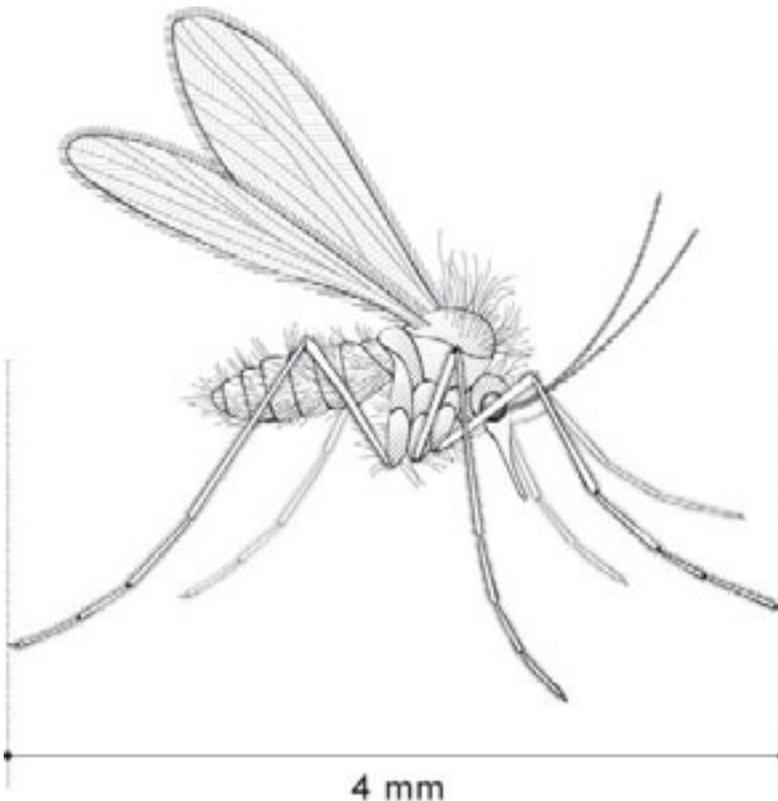
- Covering faeces / domestic waste with a thin layer of soil (less than 0.25 m non-compacted and 0.1 m compacted) may increase fly breeding since it remains a habitat but is likely to dry out more slowly.
- Controlling flies with public health pesticides should be undertaken with an understanding of the resistance status and only during outbreaks of vector-borne disease as a supplement to environmental measures. Because flies can develop resistance to public health pesticides very quickly, chemicals should be used only for a short period of time.
- IRS of the inside of pit latrine shelters is recommended to control adult flies.

T.B. 7.03 Sandflies

Sandflies are small (2 to 4 mm) bloodsucking biting flies that are important as vectors of leishmaniasis and that can cause a serious but localized biting nuisance.

Biology

The life cycle of the sandfly consists of four stages, namely egg, larva, pupa and adult. The total life cycle, from egg to adult, last from 1 to 4 months depending on the species and temperature. Females deposit 40 to 60 elongated and shiny brown eggs after a blood meal. The sandflies deposit their eggs in humid places on damp soil rich in humus, like ventilation shafts of termite hills, cracks in mud walls, and amongst tree roots. The larvae feed on decaying organic matter. Large populations of sandflies can build up at places where cattle are kept at night. The cattle provide a source of blood while the stable or house provide suitable resting places. Only the female sandfly bites and it needs several blood meals prior to laying eggs. Blood is taken from humans and animals such as dogs, livestock, snakes, rodents and birds. Sandflies become infected with leishmaniasis by ingesting blood from an infected reservoir host (e.g. domestic animals, infected people). Sandflies are able to survive in dry environments by withdrawing to cool humid resting sites during the day and become active at night.



Sandfly

Health importance

Sandflies can transmit two types of leishmaniasis: cutaneous and visceral. Visceral leishmaniasis is highly fatal. Leishmaniasis is endemic in about 90 countries in 4 continents. The saliva of sandflies can enhance the virulence of inoculated *Leishmania* parasites. Species present in the Mediterranean region can transmit sandfly fever, a viral disease also known as Pappataci fever or three day fever.

Detection

The sandflies can often only be found close to breeding places. The sandflies can only cover a radius of a few hundred meters of their breeding places as they are weak fliers. As a result, biting is restricted to areas where suitable breeding sites occur. The adult sandflies are usually active at dusk and dawn and during the night, although they can bite during the day when disturbed. They usually rest in the daytime in sheltered, dark humid sites, such as those used for breeding, but also in tree holes, caves, houses and stables; other resting places near houses are crevices in walls, stacks of firewood and rubbish.

Control Methods

Sandfly control activities should be systematically integrated, as per essential requirements (T.B. 1.08, 1.09), in endemic zones or during outbreaks of leishmaniasis and/or when there is a high presence of the vector.

Personal protection methods may additionally offer significant protection against infection and sandfly nuisance. As sandflies are still very sensitive for public health pesticides the use of impregnated mosquito nets is highly recommended. Vector control measures like Insecticide Residual Spraying (T.B. 7.15) can be effective where transmission occurs in and around the home. Where transmission occurs in the wild, people can use repellents or impregnated clothing or simply keep away from areas where sandflies are known to breed or rest. Zoo-prophylaxis (e.g. pyrethroid impregnated collars) may be a ways to control transmission from the animal reservoirs (like dogs or other domestic animals). Spraying insecticide at larval stage is usually not possible as little is known about where the larvae are.

Remarks

- Impregnated nets with mesh size of 196 holes/inch² are recommended against sandflies but, in certain climates, the reduced airflow through the very small holes can reduce the feeling of comfort under the net. An impregnated nets with mesh size of 156 holes/inch² can also be used.
- Other biting flies transmitting important diseases are the Tsetse fly transmitting African sleeping sickness and the Blackfly transmitting river blindness. Their control demands the implementation of a specific programme; the complexity of such a programme is beyond the scope of this guide.

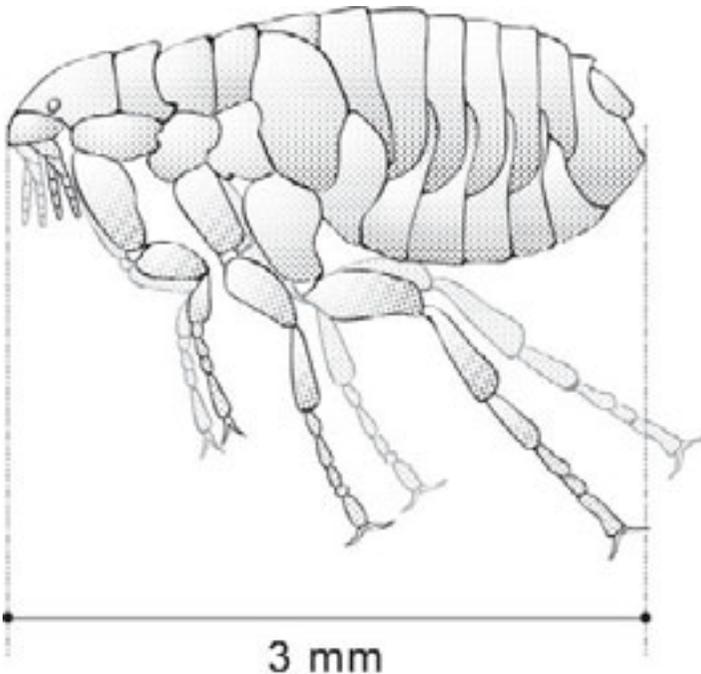
T.B. 7.04 Fleas

Fleas are small (1 - 4 mm), wingless, bloodsucking insects, in close relation with their host, that have a characteristic jumping movement. The most important species are the rat flea, the human flea, the cat flea and the sand or jigger flea.

Biology

The life cycle of fleas consists of four different stages: egg, larva, cocoon and adult. Their developmental stages all occur on land. Under optimal conditions the development from egg to adult takes 2 - 3 weeks. Both female and male fleas take blood meals. Fleas breed close to the resting and sleeping places of the host (e.g. in dust, dirt, rubbish, floor and wall cracks, carpets). Fleas may survive in their cocoon for up to a year. The vibrations of people moving into a vacant building can cause many fleas to emerge simultaneously from the cocoons, all looking for blood meals. Fleas move around by jumping; some species can jump as high as 0.25 m. Adult fleas can survive for several months without food.

The larvae of jigger fleas develop in dusty or sandy soil. Jigger fleas maintain themselves in a domestic environment by breeding on livestock and domestic animals.



Cat flea

Health Importance

Rat flea bites can cause irritation, serious discomfort and loss of blood. Human contamination may take place through a rat flea bite (plague) or through rat flea excreta (typhus). As such, dust containing rat flea excreta may be highly contaminating, if not neutralized by a chlorine solution. The human flea is in spite of its name less important. Cat fleas incidentally transmit tapeworms. Jigger fleas are a serious pest in tropical Africa. The female jigger flea burrows into the soft skin of the foot and ankle in order to lay her eggs, which can cause secondary infections.

Detection

Heavy infestations of fleas are recognized by marks of undigested blood on clothing and bedding and/or by massive skin irritation. A scratching cat or dog is an indication of a flea infestation.

Control Methods

Flea control activities should be systematically integrated, as per essential requirements (T.B. 1.08, 1.09), in endemic zones or during outbreaks of plague, Typhus and/or when there is a high presence of the vector.

Personal protection methods may offer significant protection against infection and fleas nuisance. An effective repellent, such as DEET®, applied to skin and clothing prevents fleas for a few hours from attacking. Longer lasting protection is obtained by dusting clothing with insecticide powder (T.B. 7.18) or by using impregnated clothing. Wearing shoes prevents jigger flea bites.

Fleas and their eggs, larvae and cocoons can be effectively removed by keeping houses well swept and floors washed. Due to their close relationships with rodents, long-term control of fleas is best achieved by household hygiene, elimination of food sources and through rodent control (T.B. 7.19).

Remarks

- When a flea-borne disease (e.g. plague or murine typhus) is present or threatens, flea control **must** precede rodent control. When deprived of their normal rodent host, fleas are likely to transfer to humans. The control measures during epidemics of plague and murine typhus are therefore carried out in two stages:
 1. Insecticidal dusting of rodent footpaths and habitats (T.B. 7.18).
 2. Rodent control (T.B. 7.19).
- A combined rodent and flea control using baited traps is possible using baits that combine insecticide and rodenticide characteristics. After bait ingestion, the flea will die first due to the insecticide that will diffuse through the rodents skin and the rodent itself will die later due to the prolonged rodenticide exposure.

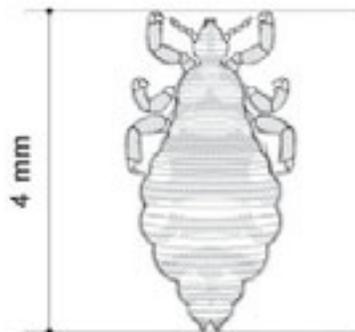
T.B. 7.05 Lice

Lice are small (3 - 4 mm) bloodsucking insects that live on the skin of mammals and birds. The species that have adapted themselves to humans are the head louse, the body louse and the crab or pubic louse.

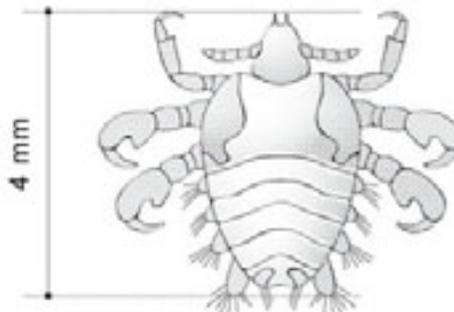
Biology

The aforementioned species live only on humans and have a life cycle that constitutes three different stages: egg, nymph and adult. Development from egg to adult takes about two weeks and occurs only in a warm environment, close to human skin. Body lice lay eggs on clothes. Eggs or “nits” of head and pubic lice are attached to hairs. They cannot be separated for long from their human host, their sole source of blood meals, and will starve to death after two or three days of separation. The lifespan of human lice is up to 30 days under optimum conditions.

A



B



Key

- A. Head louse / body louse
- B. Crab or pubic louse

Health Importance

Neither head lice nor pubic (crab) lice are vectors of disease, but they are a nuisance. Only the body louse is a vector of human diseases. It transmits Typhus fever, Trench fever and Relapsing fever. Transmission of Typhus fever and Trench fever is through louse faeces. The fine, dry faeces can infect (scratch) wounds or the mucous membranes of the nose and mouth. Humans may become infected of Relapsing fever by crushing infected body lice between the fingernails or the teeth. The disease organisms are thus released and can enter the body through abrasions, wounds or through the mucous membranes of the mouth. Bites of body lice can cause skin irritation leading to various skin infections. Lice infestations, of all species, can cause severe irritation and itching.

All lice are spread by close human contact. Body lice live in the clothing of the host and are transmitted either by direct or indirect contact (sharing of bedding, combs, clothing, towels or by sitting on infested seats). The prevalence of body lice is closely related to the socio-economic, hygienic and environmental sanitation status of any given population. Body lice are most common in colder areas where people do not frequently wash or change clothes. Human-to-human transmission of head and pubic lice is most commonly by direct contact. Head lice are generally found on children in all levels of society. The pubic louse is probably also very common but little information is available on the frequency of its infestation other than they are transmitted (not exclusively) through sexual contact and often associated with other sexually-borne diseases.

Detection

Lice are spread by close human contact and are, therefore, most commonly found on people living in overcrowded, unhygienic conditions, as in poorly maintained hospitals, jails and camps. They are also spread by direct contact between people in overcrowded transport vehicles and markets. Body lice and nits are most commonly found in clothes, mainly on undergarments, socks or clothing close to skin. They leave the clothing only to go to feed and when the blood meal is completed, they return to the fibres of the clothes where eggs are laid in the seams. Scratch marks (often with secondary infection) on the upper back, around the belt line and in the armpits may be seen. Head lice are most often found on children, primarily on the hair of the head, though they can sometimes be found in the eyebrows: presence of alive lice and/or living nits (eggs) attached to the base of the hair (particularly at the back of the neck and near the ears) and itchy scalp. Scratch marks, eczema and secondary infections may be seen. The influence of length of hair and frequency of infestation appears to be unresolved. The pubic or "crab" louse lives mainly in the pubic or genital region of the human body although it is frequently found on the eyelashes and other hairy areas (armpits, abdomen, tights) in cases of heavy infestation.

Control Methods

Lice control activities should be systematically integrated, as per essential requirements (T.B. 1.08, 1.09), in endemic zones or during outbreaks of Typhus fever, Relapsing fever, Trench fever and/or when there is a high presence of the vector.

Control measures include reduction of overcrowding and improvement of individual and community hygiene. Regular body washing and use of clean clothes usually prevents body louse infestations. Soap and cold water are not sufficient to eliminate lice from clothing. Treatment of clothing by damp heat (15 to 30 minutes at 60 °C and dry in sun) and by dry heat (ironing) must be undertaken. In areas where water is scarce, washing facilities are lacking and/or people own a single piece of clothing, this may be complicated. A more practical solution is insecticidal dusting (T.B. 7.18) or impregnation of clothing (T.B. 7.17) or to seal the clothing in a closed plastic bag for 2 weeks.

Insecticide application to the hair gives the most effective control of head lice (contact your medical referent). Head shaving is not recommend. Disinfect combs, brushes, hats and bedding of individuals infested with head lice (wash at 60°C). Examine all contacts and treat those infected.

Shaving of the infested pubic hairs from the body has been replaced by the application of insecticidal formulations (contact your medical referent). In heavy infestations, all hairy areas of the body below the neck should be treated. Simultaneous treatment of partners is recommended.

Remarks

- Because the disease organism of louse-borne typhus (and trench fever) can remain alive for at least two months in dried louse faeces, be careful when handling clothing or bedding of patients with typhus.
- If possible, inform people of the danger of crushing lice between fingernails or teeth.
- Shaving of the hair is not always culturally appropriate and without replacement/disinfection of the razor between persons it entails a risk for transmission of diseases such as skin infections, impetigo and ringworm as well as blood infections such as HIV, hepatitis B and hepatitis C.
- The use of different types of combs, sold for the control of head lice, is not effective.
- Pubic lice infestation should be regarded as a warning of the possible presence of another sexually transmitted infection and considered as an opportunity to examine the patient and provide education on the risk and prevention of sexually transmitted diseases.

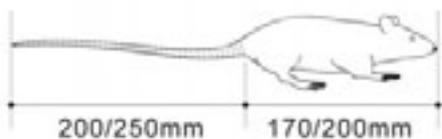
T.B. 7.06 Rodents

Rats and mice can be found in almost all human communities and the nuisance, health threats and loss of foodstuffs that they cause can be very serious. Four species are of particular health importance: the brown or Norway rat, the black or roof rat, the multi-mammate rat and the house mouse.

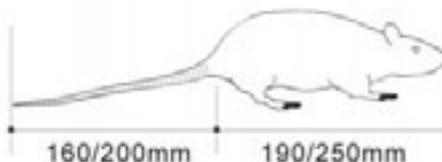
Biology

The life span of rats is up to two years under optimum conditions and three years for mice. The *brown rat* is larger than the black rat and is not well adapted to hot climates. They principally live in sewers and holes, and they feed on refuse and human excreta. Brown rats build their nests in burrows, a small snug place affording shelter or retreat. The *black rat* can be found under the roof of any type of building, where they also build their nests. If the rats live outside a building, their nest can be found on the ground, in vegetation or in trees. Black rats have a very varied diet. The multi-mammate rat is less domestic than others and can multiply rapidly. The *house mouse* nests in any place where there is soft fibrous material for making a shelter. The smallest hole a young mouse can enter is 6 mm diameter.

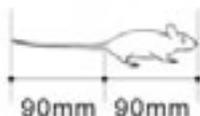
A



B



C



Key

- A. Roof rat
- B. Norway rat
- C. House mouse

Health Importance

Rodents and rodent-borne diseases may become serious problems in refugee and displaced population camps that have existed for some time. These problems may result from uncontrolled and accumulating solid waste, which greatly increases rat breeding. Rodents are associated with disease transmission to humans in a number of ways: through biting (e.g. rat-bite fever and rabies), through their urine or faeces (e.g. leptospirosis, salmonellosis, lassa fever), through infected rat fleas (e.g. murine typhus and plague), and through infected ticks (e.g. Lyme disease, relapsing fever). People can also contract leptospirosis from handling the dead bodies of infected rats or get trichinosis from eating undercooked meat from pigs that have eaten the dead bodies of infected rats. Finally, rats can cause important damage by destroying or contaminating food or drugs stocks.

Detection

Information about rodents can be collected in interviews with people. A person who is familiar with the signs and traces of rats can perform fairly rapidly a survey of a rather large area. The mayor signs are faecal droppings, rodent runways, rodent footprints or tail marks in dust and tracking powders, gnaw marks of rats / mice, burrows, and nests. Rodent odours, especially of house mice, and the typical noise produced by rodents are indicative of their presence. This information can be obtained during dusk or early evening surveys. These may be undertaken at random, or through the selection of potential trouble spots. Strong flashlights can be used to search in such places as under buildings, refuse disposal areas and harbourage. Maps are essential for this type of work and if they are not available, sketch maps should be made by the workers.

Control methods

Rodent control activities should be systematically integrated, as per essential requirements (T.B. 1.08, 1.09), in endemic zones or during outbreaks of Lassa fever, Salmonellosis, Leptospirosis, Plague and Hanta fever and/or when there is a high presence of the vector (T.B. 7.19).

Proper household hygiene may offer significant personal protection against infection and rodent nuisance.

Remarks

- Particular attention should be paid to protecting vulnerable patients from being bitten by rats. Those suffering from leprosy (due to their lack of sensations) or babies may be especially defenceless when sleeping.
- Reducing access to buildings requires careful attention as rats can pass through very small holes and can even climb vertical walls with a rough surface.
- Caution to safe handling of trapped rodents. The multi-mammate rat is the natural reservoir for the Lassa fever virus. The virus is spread through the urine of the rats. If trapped, these rats must be disposed of without direct contact between the human and the rat. This as a caged rat might urinate wildly and become covered with the virus This might also include safe handling of rodents in regards to rabies risk, especially with alive animals (e.g. drown rat in trap and handle corpse with gloves).

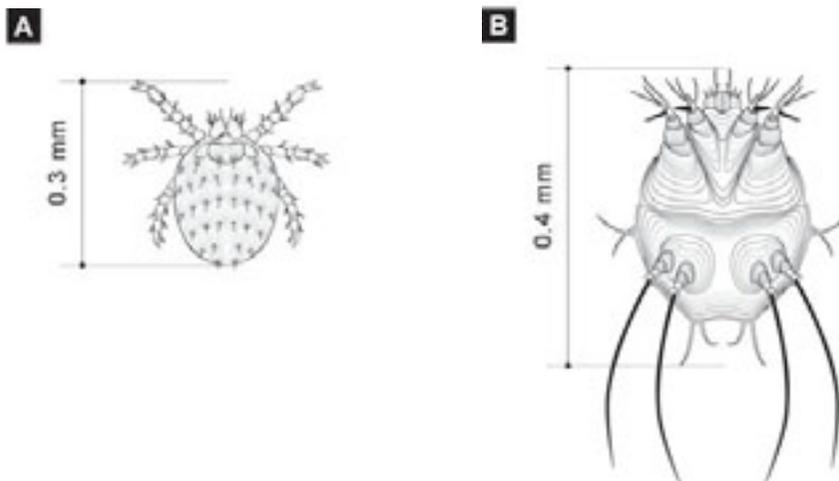
T.B. 7.07 Mites

Mites are small ectoparasites living on mammals, birds and humans. The major mite pests that are of medical importance to humans are: the biting mite or “chigger” and the Scabies mite.

Biology

The *biting mite* or “chigger” has egg, larval, nymphal and adult stages. The immature stages are similar to the adults but smaller. Only the larvae of biting mites feed on human tissue. The nymphs and adults live in the soil and feed on other mites and small insects. After emerging from the eggs, the larvae crawl onto grasses and low-lying vegetation and wait till they can attach themselves to an animal or human host. The larvae remain attached and feed on the skin of the host for between two days and a month, depending on the species. Then they drop to the ground and enter into the soil to develop into the harmless nymphal and adult stages. The mites favour bamboo bushes, but are also found in a number of other habitats with low-lying vegetation.

Almost the complete life of the *Scabies mite* is spent on and in the human skin where they feed on the epidermis of the host, procreate and lay their eggs. The total life cycle, from egg to adult, may take as little as 2 weeks. The females may live on people for 1 - 2 months. Away from the host they survive for only a few days. Fertilized female mites burrow tiny, winding tunnels in the surface of the skin progressing 2 to 3 mm per day. The tunnels can be seen as very thin twisting lines a few millimetres to several centimetres long. Larvae leave the maternal tunnel, burrow elsewhere in the epidermis or remain at the base of a hair follicle where they transform into an adult. Scabies are usually transmitted by close personal contact, for a minimum of 15 minutes, as between people sleeping together or during sexual intercourse. The scabies mites are unlikely to be acquired by someone sleeping in a bed previously used by an infested person, but may be passed on in underclothes.



Key

- A. Biting mite (larva, parasitic on animals and humans)
- B. Scabies mite

Health Importance

Biting mites can transmit a number of diseases, of which scrub typhus is the most important one. Many people show allergic reactions to mites or their bites. *Scabies mites* cause an itching condition of the skin known as scabies. Scabies results from an allergic reaction to the infection of the skin caused by the burrowing of the mites. Outbreaks of scabies are frequently reported in places where people live in overcrowded, unhygienic conditions (e.g. refugee camps) and where there is poor personal hygiene.

Detection

The presence of winding tunnels (*scabies mite*) or bites (*biting mite*) on the skin indicate mite infestation. Scabies infection can be confirmed by applying ink to infested areas and then washing it off, thus revealing the burrows. Scabies mites are commonly found where the skin is thin and wrinkled (back of knees, inside of elbows, nipples). In young children they may also be found on the face.

Control Methods

Mites control activities should be systematically integrated, as per essential requirements (T.B. 1.08, 1.09), in endemic zones or during outbreaks of scrub typhus and scabies and/or when there is a high presence of the vector.

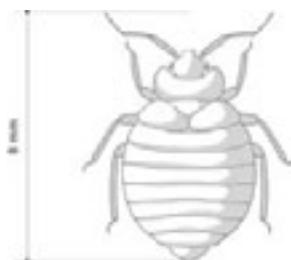
Personal protection methods may additionally offer significant protection against infection and mite nuisance. Avoid terrains infested by biting mites, wear shoes and apply repellents to skin or clothing. Under conditions of frequent exposure, the best protection is given by impregnated clothing and tucking the trousers inside the socks. Personal protection against scabies requires good general hygiene, so distribute soap and supply adequate water for laundry and washing.

T.B. 7.08 Bedbugs

Two species of bedbugs feed on humans, the common bedbug and the tropical bedbug. Both have flat oval shaped bodies with no wings and are 4 - 8 mm in length.

Biology

There are three stages in the bedbug's life: egg, nymph and adult. Complete development from egg to adult takes from six weeks to several months, depending on temperature and availability of food. Bedbugs cannot develop in temperatures below 13 °C. Adults can survive for years without food. Both male and female bedbugs feed on the blood of sleeping persons at night. The blood meal takes about 10 - 15 minutes and is repeated about every 3 days. After feeding, the nymph resembles an animated drop of blood. In the absence of humans they feed on mice, rats, chickens and other animals. During the day, bedbugs hide in dark dry places (e.g. beds, mattresses, cracks in walls and floors, furniture). Hiding places are also used for breeding. Because they have no wings, bedbugs travel only short distances. They spread from one house to another mainly in second-hand furniture, bedding and sometimes clothes.



Bedbug

Health Importance

Bedbugs are not involved in the transmission of diseases but their bites cause significant discomfort, irritation and loss of sleep. In heavily infested houses where people may receive one hundred or more bites a night, it is possible that the blood loss causes mild anaemia in infants.

Detection

Bedbugs can move rapidly when disturbed and are not easily detected while biting. A house with "bedbug" infestation may be recognized by the distinctive bed bug odour and by the blood stains of squashed bugs. Infestations can be detected by the examination of likely hiding places for the presence of alive bugs, cast-off nymphal skins, eggs and excreta (visible as small brown marks on bed sheets). Alive bugs can be detected by spraying with an aerosol spray can into cracks and crevices, thus irritating them and driving them out of their hiding places.

Control Methods

Bedbug control activities should be systematically integrated, when there is a high presence of this biting nuisance. Significant protection against infection and bedbug nuisance is offered by providing a Long-lasting insecticidal Net (T.B. 7.16) and Insecticide Residual Spraying (T.B. 7.15). This in addition to regular airing of the bedding in the full sun, improvement of the general hygiene measures, use of repellents and aerosols.

Remarks

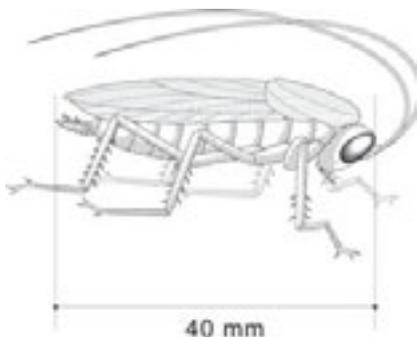
- In case of Insecticide Residual Spraying (T.B. 7.15) special attention should be given to the furniture and cracks and crevices in walls and floor. Rooms should be treated in the morning so they are dry and suitable for re-entry in the evening. Hand dusters might be used to dust mattresses and bedding, to avoid wetting them (T.B. 7.18). Bedding can also be impregnated with a safe insecticide that does not irritate the skin (T.B. 7.17).

T.B. 7.09 Cockroaches

Cockroaches are very agile and fast insects. They live in colonies and range in size from 2 - 80mm. Adult cockroaches may or may not possess wings but are always able to walk.

Biology

The life cycle of a cockroach consists of three stages: egg, nymph and adult. Depending on the species, temperature and humidity, the eggs hatch after one to three months. They reach full size between 2 and 12 months depending on the species. Cockroaches have a varied diet ranging from excreta to human food, from cardboard to clothes.



Cockroach

Health Importance

Domestic pest cockroaches have been documented to affect human health in several ways. They proliferate in the most hidden places (e.g. sewers), then thread their way everywhere and can play a role as mechanical carrier of pathogens or parasites (e.g. human intestinal parasites). Cockroaches are also known to harbour a wide variety of microbial pathogens for which they serve as potential transit host. Some people may become allergic (e.g. asthma) to cockroaches after frequent exposure.

Detection

Cockroaches are most active at night when they search for food in kitchens, food stores, rubbish bins, drains and sewers. A particular behaviour of cockroaches is their habit of regurgitating fluid from their mouth, while dropping faeces at the same site where feeding is occurring. They also produce secretions which give a persistent and characteristic odour to areas visited by them. During the day they hide in wall cracks, furniture and other secure places like bathrooms, cupboards and sewers. Cockroaches have been spotted on the face of sleeping persons feeding on their eye secretions, as well as in the mouth of snoring persons. The presence of several sizes of nymphs and egg cases is an indication of a well established colony.

Control Methods

Cockroaches control activities should be systematically integrated when there is a high presence of this vector. The key to cockroach control is cleanliness. Infestations can be dealt with by chemical control measures, followed by environmental management to deprive the cockroaches of food and shelter.

Chemical control remains the single most effective method for the control of established infestations. Several pesticide gels allows fast and drastic cockroaches eradication in health structure and warehouses by applying a few drops per m². Current practice is to use products belonging to several different classes of chemicals to delay the build-up of resistance.

T.B. 7.10 Characteristics of public health pesticides

Public Health pesticides are pesticides that are used in the control of public health significance. They include vector control pesticides, household insecticides and professional pest management pesticides. Public health pesticides can be classified into four main groups - organochlorines, organophosphates, carbamates and synthetic pyrethroids - according to their chemical structure, toxicity and precautions for use.

Principles

Toxicity and hazard levels

The toxicity of an insecticide is given as the dose required to kill 50% of a sample of test animals, often rats, in a specific time, and is referred to as the lethal dose 50 (LD₅₀). It is expressed in mg/kg body weight. The lower the LD₅₀ value, the greater the toxicity of the insecticide. The World Health Organisation (WHO) divides pesticides into five classes, according to the health risk presented by short exposure to the particular pesticide.

Class	Hazard level	User restrictions for operators
Ia	Extremely hazardous	Special licence for operator
Ib	Highly hazardous	Educated, trained operator. Must be under strict supervision
II	Moderately hazardous	Trained operator. Must carefully respect safety measures
III	Slightly hazardous	Operator must observe normal safety measures, but with attention
0	Not hazardous in normal use	Operator must observe labels and follow proper hygiene measures

Classification of public health pesticide

Organochlorines

The main representative of this class is DDT® which use has considerably declined in recent decades, mainly due to its environmental and potential health impact. DDT® has a residual effect of six months or more. It is, depending on the formulation, moderately hazardous to mammals. DDT® is not recommended for use in Insecticide Residual Spraying (IRS) activities. The other members of this family which have been used in malaria control are Lindane® and Dieldrin®. Dieldrin® had to be abandoned because of its toxicity to humans and Lindane® because of widespread resistance problems. Organochlorines are not recommended for use in health care programs.

Organophosphates

This family includes some extremely toxic public health pesticides. The organophosphates used for Insecticide Residual Spraying are low to moderately hazardous to mammals. Regular medical check-ups of sprayers and other insecticide handlers, is recommended when spraying. Organophosphate poisoning should be considered as a medical emergency, requiring immediate treatment. They have a residual effect of two to three months.

Organophosphates used for Insecticide Residual Spraying are Malathion, Fenitrothion and Pirimiphos-methyl. Temephos is an organophosphate regularly used as active ingredient in the larvicide Abate®. Temephos has a low toxicity, but some problems have occurred with resistance.

Carbamates

Carbamates are more expensive than organophosphates and are exclusively used against adult insects. Carbamates have a residual effect of two to three months, and are moderately hazardous to mammals with relatively high acute oral toxicity. The wettable powders (WP) formulations should be supplied in water soluble sachets, each one sufficient for a single pump charge. This avoids handling during weighing of the formulation and the associated exposure of the operators.

Propoxur and Bendiocarb are carbamates used as active ingredient in WP for IRS (T.B. 7.15). Bendiocarb is moderately hazardous and very toxic to fish and ducks.

Synthetic pyrethroids

Synthetic pyrethroids are widely used in public health in a variety of formulations. Synthetic pyrethroids have a residual effect of up to a year but have a low persistence in the environment. They have a relatively low mammalian toxicity, but are highly toxic to fish. The field use of pyrethroids, in the recommended concentrations, with the normal precautions for insecticide use, poses little or no hazards to applicators.

Permethrin is moderately hazardous. It is effective, provokes little or no irritation in direct contact with the skin and is widely used. Deltamethrin is moderately hazardous. It is effective and widely used. Other synthetic pyrethroids often used are Alpha-cypermethrin, Cyfluthrin, Cypermethrin, Etofenprox and Lambda-cyhalothrin

Resistance to public health pesticides

Use of pesticides on a vast and increasing scale has led to the widespread development of resistance. It is considered that the most practical approach to resistance management in spraying programs is the rotation of unrelated public health pesticides according to a pre-arranged plan in response to the results of resistance tests (e.g. from synthetic pyrethroids to carbamates). WHO has developed standard test kits for determination of susceptibility to pesticides of vectors and pests of public health importance as well as guidelines on monitoring of resistance. Ask for advice of your technical referent prior to ordering public health pesticides.

Legislation

The use of public health pesticides is regulated, depending on the country. The product should be specifically intended to be used for public health and should have received an approval by WHO Pesticide Evaluation Scheme (WHOPES). Before an insecticide is used in a particular country, it must be authorised for use in the country. The Ministry of Health can provide a list of registered public health pesticides. Gain a letter of permission for importation from the relevant authorities before purchasing, shipping and importing non-registered pesticides.

International and local markets offer a great variety of substandard pesticide and equipment products; these may fail in operational conditions and could cause unnecessary health and environmental risks. Public health pesticides are closed articles and should not be purchased locally. This to guarantee that the quality of the public health pesticides used is conform to the specifications of WHOPES. Ask for advice of your technical referent prior to ordering public health pesticides.

Remarks

- The choice of public health pesticides should not be made without the consent of your technical referent.
- Public health pesticides, conform to the specifications of WHOPES, might be made available rapidly from the MoH or the national malaria control program.

T.B. 7.11 Understanding pesticides labels

Public health pesticides should be packed and labelled according to WHO specifications. The label should indicate the content, the safety instructions (e.g. hazard warnings, recommended protective clothing) and the possible measures to be taken in case of accidental swallowing and/or contamination.

Principles

Trade names

Insecticide compounds may be sold under different names. Do not confuse these names with the type of active ingredient (a.i.). For example, a commonly used insecticide formulation for residual spraying is sold under the trade name K-Othrine®, its active ingredient however is deltamethrin.

Concentration

Following the trade name is a number that refers to the concentration. The concentration of the product represents the percentage of active ingredient (a.i.) in the formulation. Insecticide compounds are available in a number of different concentrations.

If the concentrate is 25%, it contains 250 gram a.i. per kg in the case of a powder. The amount of a.i. in liquid formulations are usually expressed as weight/volume (w/v) . If the concentrate is **25%, w/v** it contains 250 gram a.i. per litre in the case of a liquid.

In case they are expressed as weight/weight (w/w) consult the label carefully, it should also give the amount of a.i. per litre. Convert this to a percentage w/v before proceeding with the application calculations. For example, if the label indicates that the formulation is **8% w/w**, but also indicates that it contains 100 g a.i. per litre, convert this to a percentage w/v (calculation: $100 \text{ g} / 1000 \text{ ml} = \mathbf{10\% w/v}$).

The trade name does not always represent exactly the concentration. For example “K-Othrine WP 50®” contains 50 g a.i. per kg, thus only has a concentration of 5%.

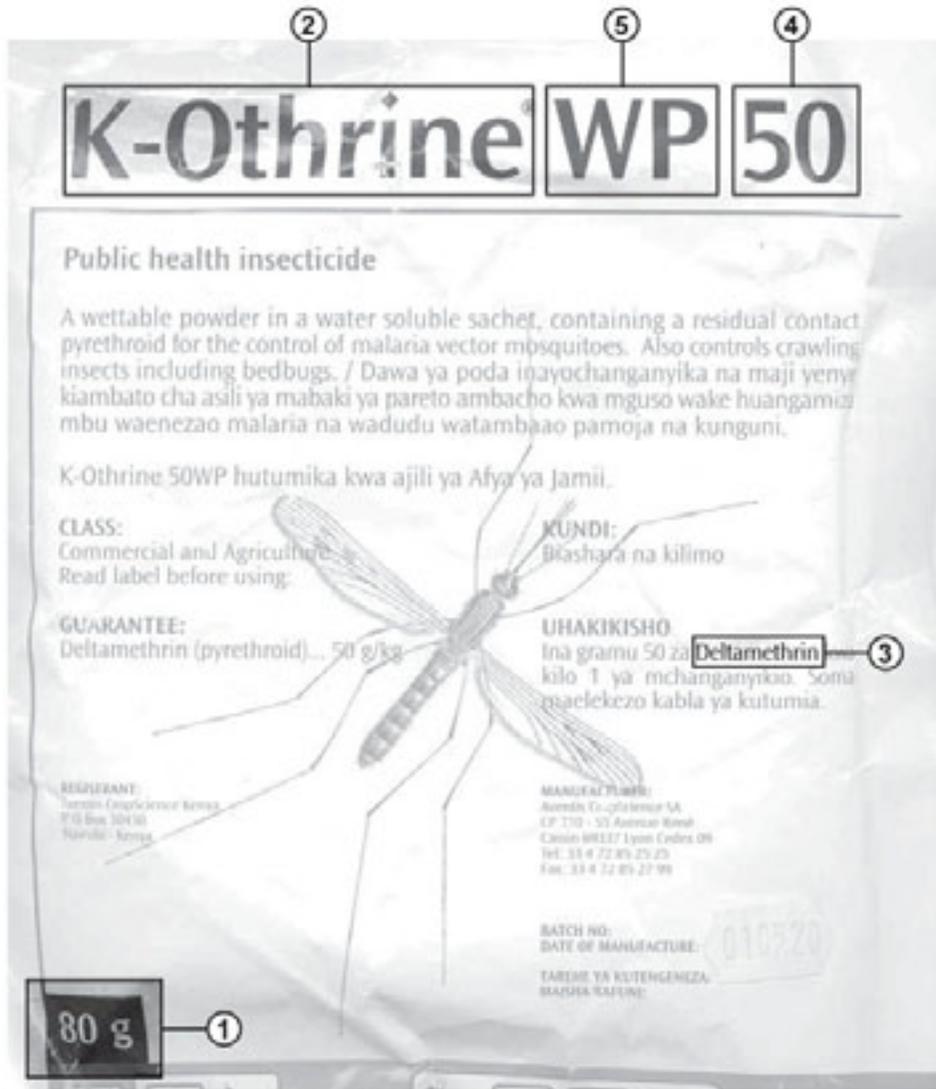
Formulation

Public health pesticides are rarely used in their pure form, but are available in special formulations, adapted to the required application method. A formulation is a mixture of one or more active ingredients (a.i.) together with other materials (e.g. solvents, carriers) to make it appropriate to use.

Following the trade name and concentration are the international codes for technical and formulated pesticides. They consist of 2 letters that indicate the type of formulation. Below are presented some of the codes.

Remarks

- Always store pesticides in their original containers.
- Consult product labels for instructions concerning storage and transport conditions.
- Public health pesticides are often classified as “toxic chemicals” and are therefore subject to strict packaging and shipping certificate requirements for transportation.
- Do not use public health pesticides left over in your stock if they are damaged or inadequately labelled.
- Public health pesticides can be purchased in many different-sized containers or tablets. They also come in pre-weighted sachets that contain the exact amount of insecticide to be diluted into a standard 10 litre sprayer; where possible it is strongly advised to use these products for ease and safety reasons.
- Sprayers used for insecticide should never be used to spray chlorine, as both product are incompatible.
- Insecticidal Residual Spraying with wettable powder can be applied on porous surfaces like brick walls, mud walls, grass structures, water based painted walls but it does not adhere well and is less effective on plastic sheeting, canvas tents and oil based paint.
- Insecticidal Residual Spraying with suspension concentrate can be applied on plastic sheeting, canvas tents, oil based painted walls but penetrates and is ineffective on porous surfaces like brick walls, mud walls, grass structures.



Key

Information provided by the label of an insecticide (example of a bag of wettable powder)

1. Weight
2. Trade name
3. Active ingredient
4. Concentration
5. Formulation

Formulation	Description of content	Application	Advantage	Disadvantage
Wettable powder (WP)	a.i. (2,5 - 80%) + inert carrier + wetting agent	IRS (T.B. 7.15), after water addition	- easy to transport, store and use - effective on porous surfaces (mud, bricks, concrete) and on water based painted walls -not expensive -good homogeneity on the treated surface -adaptable to all types of a.i.	- deposits left on surfaces - suspension needs continuous stirring - ineffective on plastic sheeting, canvas tents, oil based paint
Suspension concentrate (SC)	a.i. (10 - 50%) + wetting agent (liquid, not an organic solvent)	Insecticide Residual Spraying (IRS) (T.B. 7.15), after water addition	- easy to manipulate - good coverage of treated surface - washable - effective on smooth surfaces as plastic sheeting, tent canvas, oil based paint	- ineffective on porous surfaces and on water based painted walls - expensive - storage problems
Dustable powder (DP)	a.i. (0.5 - 10%) + inert carrier (talcum, gypsum)	Dusting (T.B. 7.18)	- ready to use (no need for water) - not expensive - easy to treat where access is difficult	- even application is difficult - emitted cloud is uncontrollable - storage problems in humid climates
Emulsifiable concentrate (EC)	a.i. (2.5 - 25%) + petroleum-based solvent + emulsifier	IRS (T.B. 7.15), after water addition	- easy to manipulate - no notable residues on surfaces -allows large distribution of a.i. -good penetration in vegetation	- expensive - smell -sensitive to cold during storage -danger of (phyto)toxicity
Granules (GR)	a.i. (0.5 - 5%) impregnated in inert carrier (kaolin, etc.)	Larviciding	- easy and ready to use - allows better penetration of dense vegetation -no storage problems	- expensive - heavy
Ultra low volume liquid (UL)	a.i. + solvent	Space spraying	- ready to use - fast action (knockdown effect) - large surfaces treated in short periods -good penetration in dense vegetation	- experience required for safe usage (operator and population safety) -wind can cause drift of the spray - expensive

- Wetting agent: allows mixing with water.
- Emulsifying agent: allows mixing with water.
- Solvent: as most public health pesticides are insoluble in water, the most commonly used solvents are gas oil, kerosene or even acetone or xylene.

T.B. 7.12 Safe packaging, transport, storage and disposal of pesticides

Public health pesticides are relatively safe; misuse is the most common problem. Still the toxic nature of public health pesticides necessitates certain precautions in their packaging, transport, storage and disposal. Expired pesticides pose a risk to people, animals and the environment. Good management of ordering / purchasing and planning of pesticide usage should minimise the need for pesticide disposal.

Principles

Packaging

- Purchase pre-packed pesticides.
- Assure that packaging of pesticide can withstand transport, handling and the climatic and storage conditions to which they will be exposed. Pesticide containers should be clearly labelled, rigid, leak proof, weather and rat resistant. Wettable powders must be packed in moisture-proof bags to maintain their good susceptibility.
- Re-pack pesticides where existing containers are damaged or deteriorating; they should also be relabelled. Place damaged paper or plastic bags containing solid formulations inside a transparent, heavy polyethylene plastic bag so that the contents and label are visible.

Transport

- Do not transport pesticides in vehicles also used for the transport of food.
- Do not transport pesticides in the driver compartment.
- Keep the vehicle well ventilated and avoid exposure of pesticides to heat and sunlight.
- Take special care when handling drums in which pressure has built up, particularly if the pressure is so high that it has caused the drum to balloon. The lids of such drums should never be removed in one movement, instead they should be opened little by little to allow a controlled release of pressure.
- Always repack drums with leaks or with worn corners at the base prior to further transport. Put straw (or other absorbent material) on the bottom of the vehicle. This should be incinerated where possible or otherwise burned on arrival.
- Load with care, pack the drums closely together and tie them down to avoid them jumping up and down.
- Protect certain powdered products against rain.
- Instruct the driver to keep public health pesticides safe from children and animals, and secure from damage and theft.
- Instruct the driver on emergency procedures in case of an accident (e.g. switch off engine and disconnect battery, keep public away, contain spills with earth or sand).

Storage

- Store pesticides in a place that can be locked and is not accessible to children or other unauthorized people. Never keep pesticides in a place where they might be mistaken for food or drinks. Storage conditions are specified on the insecticide package.
- Keep pesticides in a dry, well-ventilated place, away from sunlight and heat and separated from other chemical materials (e.g. medicines, fuel and chlorine). Some public health pesticides can convert to more toxic chemicals if they are stored at high temperatures.
- Use the older pesticides in the warehouse prior to opening newly purchased products.
- Observe strictly expiry dates specified on insecticide packaging.
- Stock containers and cardboard boxes safely on stacks with limited height to ensure stability.
- Inspect all containers regularly for damage, leaks, expiry dates and product decomposition.
- Treat leakages or spilling as follows:
 - Lay a ring of absorbent material (e.g. sawdust, dry earth or lime) around the spilled product.
 - Wet the area with a detergent solution (e.g. 10% saturated sodium carbonate solution, or a 5% caustic soda solution).
 - Scrub the floor within the ring and then sweep the solution into the absorbent material.
 - Encapsulate the absorbed material once after all liquid has been absorbed. Repeat if necessary.
 - Clean the equipment with a detergent solution.

- Raise the containers off the ground (e.g. pallets) especially if there is any risk of flooding.
- Use anti-rust paint if there is any trace of oxidation on the metal drums.

Disposal

Unfortunately, there are limited disposal methods that are safe and generally applicable under circumstances prevailing in low-income countries. As such, avoid accumulation of unwanted pesticides. Unwanted pesticide stocks may be:

- Products that are no longer needed for their intended use.
- Products that have exceeded their expiry date and should no longer be used.
- Products that have deteriorated physically or chemically to a degree that makes them unusable.
- Products that cannot be identified because their label is absent or cannot be read due to damage or language.
- Containers that have leaked, exposing products.
- Products that are bought and subsequently banned by international law and cannot be used.

Always seek advice from your technical referent prior to recycling, neutralizing, destructing or isolating expired pesticide, pesticide waste, used containers and contaminated materials.

High temperature incineration (e.g. cement factory kilns) is the preferred method for the safe disposal of the majority of unwanted pesticides. Encapsulation is an alternative in the case incineration is not an option.

In low-income countries, empty insecticide containers are often highly valued and sold or exchanged as storage containers for other materials such as fuel, chemicals and even food or drinks. Such practices are dangerous and should be prevented, for example by puncturing any empty insecticide containers that cannot be returned to the supplier for safe disposal or re-use. Outer cartons and packaging material, lightly contaminated with product residues, can be incinerated in an isolated area downwind of the nearest habitation. Plastic containers should be triple rinsed and incinerated in the way recommended for lightly contaminated packaging materials. The rinsate should be used to dilute the next spray solution or safely disposed of into pit latrines, if available, or into pits dug especially for this purpose far away from sources of drinking water. The ashes can be disposed of in an ash pit (T.B. 6.07). Non-combustible insecticide containers should not be burned. They should be encapsulated after they have been triple-rinsed and crushed or shredded. Containers may be retained as spares to replace leaking or deteriorating drums with the same product. Old and deteriorated drums can also be used as raw material at a steel smelter. They should be triple rinsed, punctured and crushed before being sent to the smelter.

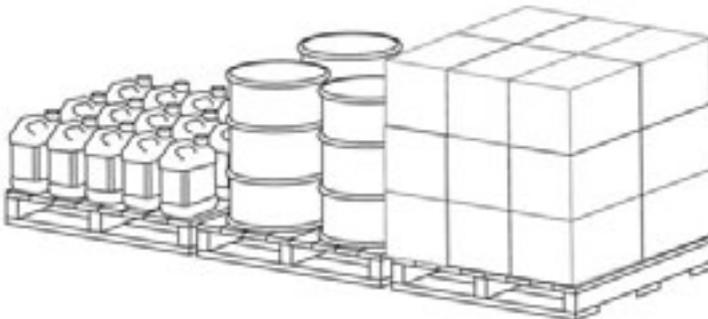
Remarks

- Some public health pesticides, such as formulations containing deltamethrin as active ingredient, are corrosive to some metals.
- Wear the appropriate clothing whenever exposure to public health pesticides is a possibility (T.B. 7.20).
- All containers should be marked "not for storage of food or water". They should be stored securely to prevent theft.
- Do not reformulate products without seeking advice from your technical referent.
- Surplus pesticides that are in good condition can be transferred to other responsible users. Transfers should ideally be carried out through a reputable pesticide supplier who is familiar with the product.
- Never pour the remaining pesticide into rivers, pools or drinking water sources. Some public health pesticides, such as pyrethroids, are very toxic to fish.
- Unwanted insecticide stocks need to be disposed of in a responsible way in consultation with your technical referent.
- Inorganic materials and organic products containing heavy metals such as mercury and lead are not suitable for incineration. Seek advice from your technical referent for a context dependent solution.

A



B



Key

- A. Improper storage of public health pesticides
- B. Proper storage of public health pesticides

T.B. 7.13 Safe use of public health pesticides

Public health pesticides are potentially hazardous if used incorrectly. They involve chemicals that are toxic to some degree. Besides the active ingredient, the formulation compounds (e.g. organic solvents) may also be responsible for side effects. Absorption by humans can occur through contact (skin), inhalation (lungs) and ingestion (mouth). It is essential that safety precautions are taken to protect both the personnel involved in chemical vector control as well as the beneficiaries.

Principles

Strategy

- Take extra precautions in choosing public health pesticides and deciding when, how, and for how long to apply them.
- Pesticides may cause local effects when they come into contact with the body, or more widespread general effects after they have actually entered the body. Pesticides can enter the body in three ways:
 - Skin contact: the skin does not act as a complete barrier and pesticides may be absorbed into the body if skin contact occurs.
 - Inhalation: pesticides may produce fumes or dust which can be absorbed through the lungs.
 - Ingestion: This mode of entry is likely to produce more severe poisoning. It may occur accidentally.

Precautions for personnel

- Read always the instructions for use and respect the application rates.
- Instruct and train properly all personnel with emphasis placed on safe practices.
- Use protective clothing (T.B. 7.20) while handling and spraying public health pesticides.
- Avoid skin contact. Never stir liquids or scoop pesticides with bare hands. If the pesticide gets on the skin, wash off immediately with water and soap.
- Use dedicated equipment for measuring, mixing and transferring pesticides. Ensure that any mixing takes place outside or in well-ventilated places. It is strongly recommended to purchase pre-packed pesticides of an appropriate quantity, even though they are more expensive.
- Take great care when opening pesticide containers.
- Do not eat, drink or smoke while working.
- Change / wash your clothes immediately if they become soaked with pesticides.
- Wash hands and face with water and soap after spraying and before eating, smoking or drinking.
- Shower or bathe using soap at the end of every day's work and change into clean clothes.
- Wash your overalls and other protective clothing at the end of each working day in water and soap, and keep them separate from the rest of the family's clothes (T.B. 7.20).
- Provide two complete sets of protective clothing and individual protective equipment to personnel involved in chemical vector control. This allows them to have one set in use while the other is being washed.
- Include information on symptoms of accidental poisoning and the immediate treatment protocol in any training aimed at those involved in a pesticide operation.
- Inform personnel repeatedly to report immediately to their supervisor if they do not feel well or in case of any incident.

If these precautions are scrupulously respected, risks are extremely limited when working with sufficiently trained personnel that is adequately supervised.

Precautions for beneficiaries

- Plan vector control activities always in consultation with the hygiene / health committees of the health structure.
- Inform patients, health structure staff or the affected community, when chemical control methods are implemented, about the type, the timeframe and associated risks of the planned activity.
- Brief the hospital staff / householders on how to recognize the symptoms of poisoning.

Symptoms of poisoning

- Symptoms of poisoning or over-exposure appear rapidly, usually within 1 hour after exposure.
- In case of poisoning with organophosphates or carbamates, nausea, headache, fatigue, and mental or muscle disorders tend to be the first symptoms, followed by vomiting, abdominal cramps, diarrhoea, heavy sweating and salivation. Critical cases may result in paralysis and breathing problems, followed by convulsions and a loss of consciousness, leading to coma, respiratory arrest and death.
- Pyrethroids have weak toxicity in mammals and only oral doses in excess of 15 g are poisonous to humans. They can cause abnormal sensations of the face, irritation symptoms of the skin and the upper respiratory tract in case of occupational poisoning (inappropriate handling). In case of poisoning due to ingestion, initial symptoms are mainly digestive (epigastric pain, nausea and vomiting).

Safety instructions for dealing with pesticide poisoning:

All the staff should be fully aware of the following simple rules to follow in case of a pesticide poisoning:

- Remove patient from contact with pesticide.
- Act calmly, keep patient comfortable and strictly at rest.
- Remove contaminated clothing, wash exposed skin thoroughly with water and soap.
- Flush the eyes with large amounts of clean water for approximately ten minutes when pesticide has come into contact with them; eyelids should be kept open during flushing.
- Pay attention to breathing, give artificial respiration if required.
- Lay patient on their side in the safety position.
- Induce vomiting if highly toxic material has been swallowed, but only if the patient is conscious.
- Get medical assistance.

Remarks

- Medical staff should be aware of which pesticides are being used and the actions that need to be taken in case of poisoning. Use of some pesticides like rodenticides requires presence of antidotes. A stock of injectable atropine must be kept at hand in case of potential organophosphate and carbamate poisoning.
- Supervisors of staff working with pesticides must be able to quickly diagnose a case of poisoning and take the appropriate actions.
- Protective clothing can be an important source of exposure to operators if it is not either carefully washed or discarded after use.
- In low-income countries, empty pesticide containers are highly valued and often sold or exchanged as storage containers for other materials, even for food and drinks. Pesticide containers can never be made sufficiently clean to be safely used for storing food or drinks. Such practices are dangerous and should be prevented, for example, by puncturing and encapsulation of all empty pesticide containers that cannot be returned to the supplier for safe disposal or re-use.
- Always have a shower system available (e.g. bucket of water and soap).

T.B. 7.14 Insecticide residual sprayer

Suitable spraying equipment that is properly used ensures a safe application of insecticide applied uniformly at the recommended dosage over all sprayed surfaces on which vectors may rest, like ceilings, walls and the lower surfaces of large furniture.

Principles

Application of spray

- Use a hand compressed sprayer consisting of a tank holding a liquid insecticide formulation, which can be pressurized by means of a hand pump fixed to it. The compressed air forces the liquid out the tank via a hose with a cut-off valve, a lance and a nozzle.
- Spray the insecticide suspension evenly at the recommended dosage. The following factors determine how much insecticide is sprayed on a surface:
 - The concentration of insecticide in the suspension (generally 1 pre-weighted sachet or dose per 10 litres sprayer).
 - Type of nozzle (the flat spray nozzle used for wall spraying produces a spray with an angle of 80°).
 - The discharge of the sprayer (760 ml/min at tank pressure of 280 kPa).
 - The air pressure in the sprayer (maintain at 170 - 380 kPa).
 - The distance from the nozzle tip to the surface being sprayed (0.45 m).
 - The speed of application over the surface (19 m² per minute).
- Respect these factors so that the application rate will be 40 ml/m² (calculation: 760 ml/min divided by 19 m²/min = 40 ml/m²). This means that 10 litres of spray suspension can spray 250 m² (calculation: 10.000 ml divided by 40 ml/m² = 250 m²).

Check sprayer

- Use WHO approved hand operated compression sprayer.
- Examine the sprayer to ensure that all parts are present, assembled correctly and in good condition.
- Check that the correct type of nozzle is fitted and that it is not damaged or eroded.
 - The flat-fan nozzle (E8002) delivers a fan-shaped spray, and is used for residual wall spraying. This flat-fan nozzle produces a spray with an angle of 80° and 760 ml per minute at a standard tank pressure of 280kPa.
 - The solid stream nozzle is used to treat cracks and crevices for control of bedbugs, soft ticks, cockroaches and ants.
 - The hollow-cone nozzle can be used to spray breeding sites of mosquitoes but also tick and mite habitats in vegetation.
 - The solid-cone nozzle is used to spray mosquito breeding sites.
- Protect the nozzle by putting the lance in the bracket and nozzle cup of the sprayer when it is not in use.

Test spraying with water

- Wear protective clothing (T.B. 7.20).
- Use clean water to ensure that the equipment operates properly and does not leak before using an insecticide (often a cause for poisoning).
- Pour clean water through a sieve into the tank and never fill the tank more than 3/4 full.
- Fit the lid and turn the handle to lock the lid into position.
- Operate the pump using both hands and with a foot on the footrest. Pump to the full working pressure. The lower and upper limits for the working pressure are 170 kPa (25 psi) and 380 kPa (55 psi).
- Maintain pressure between these two values during spraying by occasional re-pumping. If you hear a hissing sound of escaping air, the tank is losing pressure, most probably via an accessory on the tank, and this should be repaired.
- Check to make sure there are no leaks along the lance and hose, especially where the hose joins the tank and the trigger on / off valve.
- Operate the trigger on / off valve to make sure that spray is emitted.
- Check the spray pattern from the nozzle by spraying a dry wall surface. Look to see that the pattern is even and without streaks. Ensure that the nozzle does not drip when the trigger on / off valve is released.

Checking nozzle discharge

- Pump to the full working pressure.
- Open the trigger on / off valve for one minute, collect the discharge and measure the amount in a measuring jug. Repeat this procedure a further two times and calculate the average discharge.
- The discharge should be about 760 ml/min. If the discharge is incorrect, check the nozzle and the screen filters to ensure they are not clogged. If necessary, replace the nozzle. Repeat the discharge test until the correct volume is obtained.
- The opening in a nozzle is very small and must not be damaged. Clogged nozzles should be put in clear water for several hours before the blockage is removed by a very soft toothbrush. Never clean a nozzle with a hard pin or a piece of wire, and never put the nozzle to your mouth to blow through it.

Preparation of the insecticide spray

- Identify a suitable WHOPEs approved insecticide for public health use. Most public health pesticides available for residual spraying come in pre-weighted sachets that contain the exact amount of insecticide to be diluted into a standard 10 litres sprayer. Note that different surfaces such as grass or plastic sheeting might require a different insecticide or formulation (T.B. 7.11).
- Obtain, where possible, the water required for the mixing of insecticides on site.
- Prepare the insecticide spray according to the manufacturer's instructions in a separate recipient, mix thoroughly and pass it through a sieve when pouring it into the sprayer. Never fill the tank more than 3/4 full.

The Spraying technique

- Pump until the pressure gauge shows 380 kPa (55 psi).
- Spray a vertical swath from roof to floor, using a downward motion, to complete one swath.
- Time your spray speed to cover one meter every 2.2 seconds, i.e. 4.5 seconds for a 2 m high wall. Timing may be aided by mentally counting "one thousand and one – one thousand and two – one thousand and three -...".
- Step sideways and spray upwards from floor to roof, using an upward motion. Respect an overlap of 5 cm with the previous swath.
- Keep the spray tip about 45 cm from the wall to ensure the correct swath width of 75 cm wide. Lean forwards as you spray from top of the wall and move back as you bring the nozzle downwards. Move forward again when you are approaching the floor.
- Shake the tank regularly to maintain a homogeneous formulation.
- Do not let spray drip on the floor.
- Continue to spray the whole surface with alternating downwards and upwards motions.
- Do not expose a pressurised pump to the sun.
- Re-pressurize the tank when the pressure gauge falls below 170 kPa (25 psi).

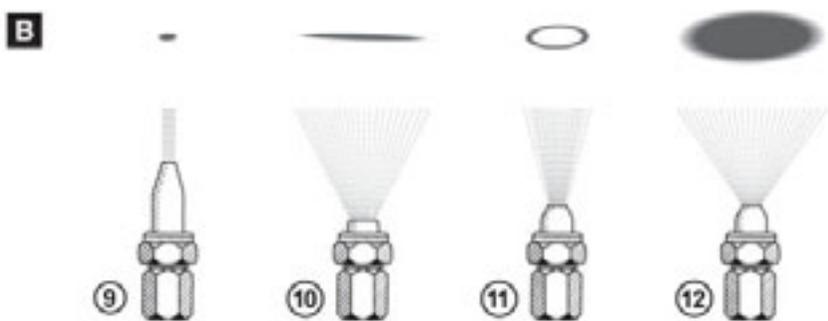
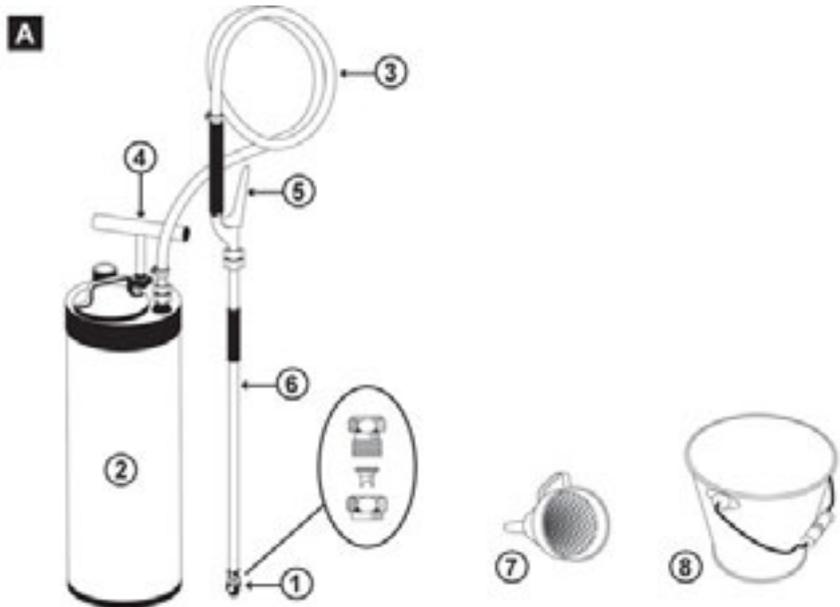
Cleaning and storage of equipment after use:

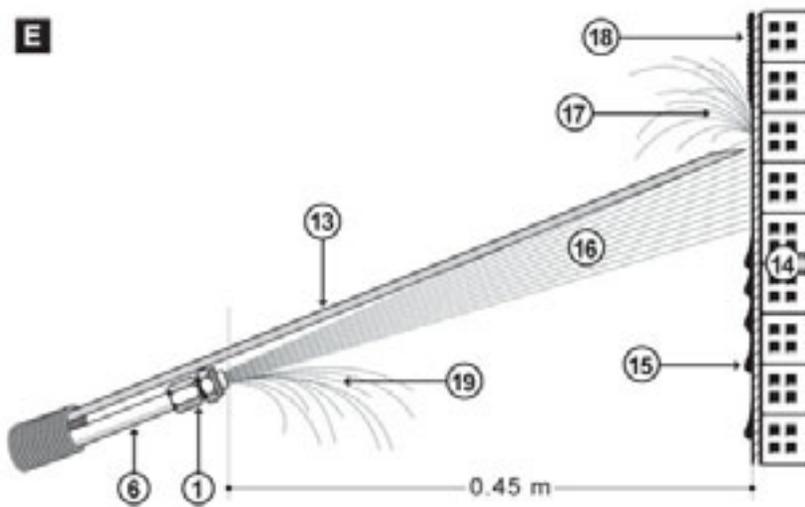
- Empty the spray tank after use; never store a spraying product in the apparatus. Latrine walls can be sprayed with remaining insecticide solution in the tank (T.B. 7.02).
- De-pressurize the tank. Pour out any remaining insecticide into pit latrines or a specific infiltration pit; any insecticide needs to be diluted with more water before being put into pits.
- Fill the tank half-full with clean water.
- Close the lid, pump up to 380 kPa (55 psi) pressure and spray water through the nozzle.
- De-pressurize the tank, and shake it so that all inside surfaces are washed.
- Pour out any remaining water into pit latrines or into a specific disposal pit.
- Remove, clean and reassemble the spray filter which is located in the valve handle.
- Remove, clean and reassemble the nozzle tip.
- Check parts (such as nozzles and seals) carefully for signs of wear.
- Ensure that the moving parts are lightly oiled regularly.
- Clean the outside of the tank.
- Turn the tank upside down with an open lid, open the on / off valve and let all the water drain out of the hose and lance.
- Ensure the lance is placed in its holder when not in use; this protects the nozzle. When storing the sprayer for a long period hang it upside down with the lid open to allow air circulation.

Remarks

- When spraying smooth surfaces, such as plastic sheeting, tent canvas, oil based paint, the run-off might be too important when the spray speed to cover one meter is every 2.2 seconds. In this case double the application speed, wait until the sprayed surface is dry and spray a second time in order to obtain the recommended dosage (g a.i./m²).
- Both the insecticide and the spraying equipment must be WHO Pesticide Evaluation Scheme (WHOPES) approved. It is strongly recommended to order public health pesticides through your technical referent. Suitable public health pesticides can possibly be made available locally by the Ministry of Health or national malaria control programs.
- Spray persons must use protective clothing (T.B. 7.20) and use public health pesticides safely (T.B. 7.13). In hot and humid climates, the wearing of protective clothing may be uncomfortable. Public health pesticides should therefore be applied during the cooler hours of the day, to minimize neglect of the safety rules.
- Set up a training area for practical training so that each spray man can learn the correct spraying technique to spray at the proper rate to cover 19 m² per minute. Nine vertical strips must be sprayed. The spray men should spray at an uniform rate starting at the top left corner of the wall and moving downwards to the bottom. A distance of 45 cm must be kept between the nozzle tip and the surface area. To keep this distance during training, a wooden stick can be attached to the lance.
- Be aware of the need for spare parts when planning a spraying operation; e.g. nozzle tips need to be changed every 20 working days.
- Regular cleaning and maintenance of compression sprayers is essential to ensure optimum performance and to maximize their working lifespan.
- Always carry out cleaning / maintenance wearing the appropriate protective clothing.
- Respect the precautions during spraying: do not smoke, do not eat, do not drink, avoid touching other people, wash hands and remove protective equipment after spraying. Do not spray when it is windy.

Key	Input
A. WHOPES approved hand operated compressor sprayer	- Hand operated compressor
1. Nozzle	- Nozzles (solid stream, flat fan, hollow cone, solid cone)
2. Spray tank	- Bucket
3. Hose	- Sieve
4. Pump	- Measuring container
5. Trigger on / off valve	- Chronometer
6. Lance	- Insecticide
7. Funnel with sieve	- Toothbrush
8. Bucket for insecticide spray preparation	- Protective equipment (hat, face shield, face mask, overalls, gloves, apron, boots)
B. Types of nozzles	- Vertical surface (19 m ²)
9. Solid stream	- Wooden stick
10. Flat fan	
11. Hollow cone	
12. Solid cone	
C. How to unplug a nozzle	
D. Spraying technique	
E. Nozzle discharge pattern on vertical surface	
13. Wooden stick attached to the lance	
14. Wall	
15. Run-off	
16. 80° fan	
17. Rebound	
18. Deposit of insecticides	
19. Fallout	



D**E**

T.B. 7.15 Insecticide Residual Spraying campaign

Insecticide Residual Spraying (IRS) is widely used for vector control, especially against mosquitoes, triatomine bugs and sandflies. Its objective is to ensure the safe and correct application of a residual insecticide to surfaces on which vectors may rest, usually ceilings, walls and the lower surfaces of large furniture. Spraying may need to be repeated at least every 6 months depending on the length of the transmission season and the residual life of the insecticide on the treated surface.

Principles

Essential conditions for the success of an IRS campaign are:

- The ability to assess whether malaria prevention is appropriate for the target group (Chapter 1, section 7.2.3).
- The local vector enters habitations to feed and rest indoors after feeding.
- The local vector is not resistant to the insecticide intended to be used.
- The majority of the population lives in shelters with plain walls, such as huts, tents or houses. Huts made of branches with wide voids or gaps will be difficult to spray.
- The population sleeps indoors during the main biting period of the vector.
- The population is not nomadic; the structures should be (semi-) permanent and not changing within the next week / month.
- The willingness of the population to accept spraying.
- The capacity to organise the spraying activities on time. The ideal time to implement the IRS campaign requires a review of previous malaria data. In areas where transmission is seasonal, the implementation should be done preferably before the increase in transmission. In areas of intense all year-round transmission, the IRS will be highly effective whenever it is implemented given that spraying is repeated at least every 6 months (depending on the residual life of the insecticide used as per box C).
- The ability to collect and map the location and number of shelters to be sprayed.
- The capacity to spray a high enough proportion of houses and rooms in the target area to ensure that the majority of mosquitoes are exposed to the insecticide or that more than 80% of the shelters will be correctly sprayed to ensure mass protection effect.
- The spray team is trained in the safe and effective application of insecticides.
- The ability to organise an information campaign for the targeted population about IRS, its purpose and benefits. The information to be disseminated will depend on the outcome of the assessment. Without the support of the hospital staff and/or the community, its leaders and the authorities, an IRS campaign will most probably not be successful.

Insecticide requirements

- Estimate the total surface A (m²) to be sprayed considering the number of units to be treated and the average surface area of each unit (m²). Doors and windows must be sprayed inside and outside. Walls and ceilings must be sprayed indoors. Floors and outside walls will not require spraying.
- Determine the type of surface (mud, grass, brickwork, plastic sheeting, oil / water paint) to be sprayed.
- Identify a suitable WHOPEs approved insecticide for public health use (box C). Note that different surfaces such as grass or plastic sheeting might require a different insecticide or formulation (T.B. 7.11). Before an insecticide is used in a particular country, it must be authorised for use in the country (T.B. 7.10).
- Be aware that most public health pesticides, available for residual spraying come in pre-weighted sachets that contain the exact amount of insecticide to be diluted into a standard 10 litres sprayer.
- Note that one 10 litres sprayer can spray 250 m² (T.B. 7.14). Determine the amount of pre-weighted sachets to be ordered based on the total surface A (m²) to be sprayed.
- Calculate, in case the insecticide is supplied in bulk, the exact amount of insecticide to be diluted into a standard 10 litres sprayer as per box A, B or C. Given that one 10 litre sprayer can spray 250 m², calculate the total amount of insecticide required based on total surface A (m²) to be sprayed.

The spraying team

- The number of people needed will depend on the context (e.g. the level of the emergency, skills and experience of the team, the climate, the terrain, the number and density of the shelters, the logistical support). The area that can be sprayed by one spray person can be estimated between 1000 and 2000 m² per day. Determine the amount of sprayers to be ordered based on the total surface A (m²) to be sprayed.
- To make the spraying efficient, employ a minimum of two people per hand compressed sprayer tank. One to do the actual spraying. One accompanier, possibly a community health worker, to make sure the shelters are empty before the actual spraying and to deliver information about disease transmission and the purpose and benefits of IRS. Potentially also to install a LN and instruct on how to use it.
- For safety reasons, a working day for spray persons will depend on the density of households. According to the duration of spray person's exposure, a working day will vary from 4 hours (high concentration of households) to maximum 6 hours (lower density of households).
- A team may consist of a team leader and up to 5 spray persons and 5 accompaniers, according to the specific features of each location to be sprayed. One supervisor can follow-up on a maximum of 4 teams.
- A storekeeper should be assigned to the IRS campaign to follow-up on the preparation, distribution, inventory and maintenance of the material.
- A training should be organized for all the staff involved with the IRS. Often, such a training will last around two days and should include:
 - some basic information on the *Anopheles* mosquito and malaria transmission (T.B. 7.01 and section 7.2.3),
 - delivery of basic messages about the disease addressed, its symptoms and the importance of seeking early treatment,
 - the objective of the IRS campaign and the importance of quality work,
 - basic information on public health pesticide (T.Bs. 7.10, 7.11, 7.12),
 - how to operate, clean and maintain the sprayer (T.B. 7.14),
 - infrastructure preparation prior to spraying (e.g. food and eating utensils removal),
 - safety aspects when handling public health pesticides (T.B. 7.13),
 - diagnostic and treatment of pesticide poisoning (T.B. 7.13),
- It should be verified that the sprayer persons wear their protective equipment appropriately (T.B. 7.20).

The infrastructure

- Inform the head of the household of the spraying schedule and the purpose of spraying, giving them time to prepare and vacate the building.
- Have the walls, where possible, be cleaned prior to spraying to prevent the removal of the insecticide residue by cleaning after spraying.
- Assure that occupants leave the building before spraying. Rooms occupied by sick people who cannot be moved must not be sprayed.
- Remove all household items, including water, food, cooking utensils and toys from the building and protect them against the rain. Items that cannot be removed should be well covered. Move and cover, or take out the furniture to allow easy access for spraying the walls.

Spraying

- Ceilings must be sprayed with particular attention to all beams. Spraying movement should be as for walls. Do not stand directly below the spray fallout.
- Furniture and objects against the wall should, as far as possible, be moved in order to spray behind them. Cupboards must be emptied so they can be sprayed inside. Tables must be carefully cleaned to remove spray fallout.
- Spray persons must use protective clothing (T.B. 7.20) and use public health pesticides safely (T.B. 7.13). In hot and humid climates the wearing of protective clothing may be uncomfortable. Public health pesticides should therefore be applied during the cooler hours of the day, to minimize neglect of the safety rules.

Procedures after spraying

- Advise the occupants to stay outside for two hours after spraying.
- Instruct the hospital staff or the householders to sweep or mop the floor and all flat surfaces to remove the spray fallout before patients, other persons or items are allowed to re-enter. Instruct them not to clean the sprayed surfaces.
- Assure that all empty packaging is returned to the supervisor for safe disposal. Organize appropriate disposal of remains of insecticide and empty packaging (T.B. 7.12).
- Never pour the remaining insecticide into drinking water sources or rivers and pools as fish are highly sensitive to pyrethroids.

Box A

Application of wettable powder / granules: (for use on porous walls like bricks, mud, grass structures, water based painted walls).

One litre of spray suspension can be prepared using the following formula:

$$X = S \times Y \times 100/C$$

With:

X = weight of water-dispersible powder/granules required to prepare one litre of spray suspension (g)

Y = recommended dosage (g/m²); depends on the insecticide (box C)

C = concentration of active ingredient in formulation as mentioned on the packaging (%)

S = 25 m² of surface covered by one litre of spray suspension; if standard spraying procedure is used, spray is applied at 40 ml/m² or 1 l/25m² (T.B.7.14)

Example: deltamethrin (2.5% wettable powder) is to be sprayed at a dosage of 0.025 g a.i./m².

$$X = 25 \times 0.025 \times 100/2.5 = 25 \text{ g}$$

For a 10 litres tank the amount of wettable powder needed is 250 g (calculation: 10 x 25 g).

Example: alphacypermethrin (5% wettable powder) is to be sprayed at a dosage of 0.03 g a.i./m²

$$X = 25 \times 0.03 \times 100/5 = 15 \text{ g}$$

For a 10 litre tank the amount of wettable powder needed is 150 g (calculation: 10 x 15g).

Box B

Application of suspension concentrate: (for use on canvas tents, plastic sheeting, oil based painted walls).

One litre of spray suspension can be prepared using the following formula:

$$X = S \times Y \times 100/C$$

With:

X = amount of suspension concentrate needed to prepare one litre of spray suspension (ml)

Y = recommended dosage (g/m²); depends on the insecticide (box C)

C = concentration of active ingredient in formulation as mentioned on the packaging (%weight/volume)

S = 25 m² of surface covered by one litre of spray suspension; if standard spraying procedure is used, spray is applied at 40 ml/m² or 1 l/25m² (T.B.7.14)

Example:

Alfacypermethrin (6% suspension concentrate) is to be sprayed at a dosage of 0.03 g a.i./m².

$$X = 25 \times 0.03 \times 100/6 = 12.5 \text{ ml}$$

For a 10 litre tank the amount of suspension concentrate is 125 ml (calculation: 12.5 ml x 10).

Pour this in a recipient and top-up with water to 10 litre.

Box C

(adapted from Whopes list of approved insecticides for IRS – for updates see Whopes website)

Insecticide compounds and formulations (1)	Class group (2)	Dosage (g a.i./m ²)	Mode of action	Duration of effective action (months)
Malathion (WP)	OP	2	contact	2 - 3
Fenitrothion (WP)	OP	2	contact and airborne	3 - 6
Pirimiphos-methyl (WP and EC)	OP	1 - 2	contact and airborne	2 - 3
Bendiocarb (WP)	C	0.1 - 0.4	contact and airborne	2 - 6
Propoxur (WP)	C	1 - 2	contact and airborne	3 - 6
Alpha-cypermethrin (WP and SC)	P	0.02 - 0.03	contact	4 - 6
Bifenthrin	P	0.025 - 0.05	contact	3 - 6
Cyfluthrin (WP)	P	0.02 - 0.05	contact	3 - 6
Deltamethrin (WP, WG)	P	0.01 - 0.025	contact	2 - 3
Etofenprox (WP)	P	0.1 - 0.3	contact	3 - 6
Lambda-cyhalothrin (WP, CS)	P	0.02 - 0.03	contact	3 - 6

(1) CS: capsule suspension; EC: emulsifiable concentrate; SC: suspension concentrate; WG: wettable granules; WP: wettable powder; (2) OC : Organochlorines ; OP : Organophosphates ; C : Carbamates ; P : Pyrethroids

Remarks

- Both the insecticide and the spraying equipment must be WHO Pesticide Evaluation Scheme (WHOPES) approved. It is strongly recommended to order public health pesticides through your technical referent. Suitable public health pesticides can possibly be made available locally by the MoH or national malaria control programs.
- Respect the precautions during spraying: do not smoke, do not eat, do not drink, avoid touching other people, remove protective equipment after spraying and wash hands.
- Insecticides are often classed as “toxic chemicals” and are therefore subject to strict packaging and shipping certificate requirements for transportation. Packaging requirements for wettable powders are less strict than for liquid formulations and the wettable powders are normally the most simple formulations to ship by air transport.
- Some insecticides can give allergic reactions, such as skin rash. It is therefore important to ventilate the sprayed surface and try to prevent people entering the infrastructure before the insecticide has dried. The time needed for the insecticide to dry is context dependent. A piece of toilet paper applied on the sprayed surface can be used to confirm if it is dry or not.
- Before starting up and training a team, find out if suitable people are available in the region (e.g. a lice control team is not trained to manage a program to control malaria and will need additional training).
- IRS is especially recommended in area's where malaria transmission is largely confined to one season. IRS can then be very effective when conducted once a year prior to the start of the transmission season. In area's where malaria transmission is more or less constant throughout the year, IRS will need to be repeated every three to eight months (according to local conditions, habitation types and insecticide used), with both cost and human resource implications.
- The nature of the sprayable surface plays a major role in the duration of the residual effect of the insecticide. Surfaces of organic origin (e.g. wood, bamboo, palm leaves or thatch and mud) are adsorptive and may break down the insecticide chemical structure. They require higher application rates to achieve satisfactory residual action. Alkaline surfaces such as whitewashed walls affect insecticides. Do not spray a corrugated iron roof exposed to the sun as the heat that will build up may rapidly inactivate insecticides or cause it to flake off the sprayed surfaces.

T.B. 7.16 Long-lasting insecticidal Nets (LN's)

Long-lasting insecticidal Nets are one of the major ways to control malaria, and they are widely accepted by communities in areas affected by malaria. They have two kinds of protective effects – one for the people directly under the nets, and one for the community at large.

Principles

Personal protection and mass effect

The personal protection effect of a Long-lasting insecticidal Net (LN) for the people sleeping under it operates in three ways. First of all, the insecticide incorporated in the net tissue kills the mosquitoes (and/or other biting insects) that come into contact with the net. Secondly, the LN repels a proportion of the mosquitoes but this ability depends on the insecticide present in the net. Thirdly, the net acts as a mechanical barrier to biting. The mechanical barrier provides less protection, which is why nets without insecticide are less effective than treated ones. A torn untreated net offers little or no protection, whereas a torn treated net still works to some extent.

The mass effect is important but often ignored. It extends the protection beyond that of the individuals under the net and works in three ways. Firstly, mass coverage by LN's shortens the lifespan of the mosquitoes. Secondly, mass coverage reduces the number of mosquitoes in the community. Apart from their killing effect, nets will also inhibit mosquitoes feeding, hence reducing their reproductive potential. Thirdly, with some *Anopheles* species, mass coverage might divert mosquitoes from human to animal biting, thereby reducing human to human transmission. Taken together, these effects on the vector population can greatly reduce transmission of disease, but only if the coverage of mosquitoes nets is sufficiently high.

The personal protection provided by LN's allows their deployment in a progressive way starting with low population coverage. Nonetheless, rapid scale-up with a target of complete coverage is highly desirable as the mass vector control effects of LN's become more apparent when household coverage increases. Every LN used contributes thereby not only to the safety of its user(s), but also to the safety of others.

Characteristics

LN's are ready-to-use factory pre-treated nets with the insecticide either incorporated or coated around the fibres. Long-lasting insecticidal Nets retain their insecticidal properties for two to five years, the physical lifespan of the net. A LN only needs re-treatment after 20 washes. As a consequence, and if used in a normal way, they do not require further treatment during their normal life. Polyester and polyethylene are currently the most common fabrics for nets, but cotton fibre is also used. A square shaped net has the least person-to-net contact and is often preferred. An entrance flap is not recommended. The mesh size indicates the number of openings per square inch in the net; 156 is the most common. In tropical climates a mesh size higher than 156 may result in insufficient ventilation for comfortable use. However in desert fringes where it is cold at night, the "demuria", a non transparent net, might be the better choice. The "denier" value of a net is an indication of the weight of the fibre and consequently its strength. Nets with a denier value of less than 100 are not recommended due to the relative ease of tearing. In practice, the size of the net is a matter of user preference and it is culturally determined.

Essential conditions for the success of a LN's distribution are:

- The ability to assess whether a LN is appropriate for the target group (Chapter 1 and section 7.2.3).
- At least some of the vectors bite at hours when and where people are sleeping under the net.
- There is a potential for behaviour change so that people will use the nets correctly, knowing that the distribution of nets should be accompanied by clear LN promotion / education messages.
- The population is willing to and can use the nets (e.g. shelters are large enough to put up a net).
- The population do not make fire in the sleeping area of the shelter.
- Ability to organise and implement an effective community promotion campaign prior to distribution. The information to be disseminated will depend on the outcome of your assessment. Without the support of the hospital staff and/or the community, its leaders and the authorities, a LN distribution will most probably not be successful.
- An adequate delivery system including the acquired information on number and location of houses and sleeping units requiring nets.
- LN's are available or can be made available in time. Long commercial delivery and shipping times might be experienced with LN's and this may delay deployment and effective protection.
- Ability to manage the distribution to targeted groups in the required time frame. The ideal time to implement the distribution requires a review of previous malaria data. Implementation should be done preferably before the start of the malaria season in area's where transmission is seasonal. In areas of intense all year-round transmission of malaria, distribution will be effective whenever it is implemented.
- Distribution of nets will not endanger the population (e.g. risk of theft, looting).
- The mosquito species are not resistant to the insecticide used to impregnate the LN's.

Activity plan for LN distribution

- Define the size, shape and colour of the nets to be distributed. LN's are available in rectangular and circular forms, multiple colours and in transparent or opaque cotton sheet (e.g. the Dumuria). Distribute in an emergency the model available in stock to enable rapid deployment (e.g. rectangular 1.30 m wide individual LN for patients in health centres and rectangular 1.90 m wide LN for families).
- Define the beneficiaries. A targeted distribution to risk groups (e.g. like pregnant women and children under 5 in open settings through clinics with antenatal care, immunization programmes, feeding centres or vaccination campaigns) or a mass distribution, aiming at good household coverage.
- Define how and where the nets will be distributed (e.g. mass distribution during a general food distribution, through local leaders or a house to house distribution installing the LN's during the distribution which has a positive impact on their utilisation).
- Define a well-prepared LN promotion / education campaign. Contact your technical referent to receive already existing survey forms that have nevertheless to be adapted to the data collected on the local context (T.B. 1.01).
- Define a post-distribution monitoring method to ensure that targeted beneficiaries have actually received / retained and are using their LN correctly.

Remarks

- In refugee or displaced camp settings, Insecticide Residual Spaying (T.B. 7.15) is likely to be preferable to the distribution of LN's due to the notoriously poor retention rates for LN's in the acute emergency phase. Faced with limited food rations, families will often choose to sell their net as a means of temporarily increasing the family food intake.
- LN use can result in rashes or allergic reactions, so it is advisable to ventilate the nets 24 hours before using them. When handling a large number of new nets, protective clothing (gloves and long sleeves) should be used by the staff.
- To reduce the risk of re-selling of LN's by the beneficiaries, the nets should be taken out of the packaging, marked with a number or name and signed for reception by the head of the household. Some LN's are already supplied with an individual number printed on them. This can also help with monitoring of the distribution, and to assess how well predefined targets are reached.
- In places where a pre-distribution study shows that the nets distributed to pregnant women are largely used by their husband or other relatives, distribute two nets for each pregnant woman.
- Where possible, nets should be ordered well in advance of a planned distribution, to ensure timely delivery and appropriate transportation costs.
- The shape and colour are important considerations, as some colours may be refused / misused by the beneficiaries because of the significance of certain colours to that population (e.g. white nets might be misused to wrap dead bodies or make wedding dresses). White nets may also be washed more often than coloured nets.
- A valuable LN's intervention in malaria endemic countries is allocating one net per bed in the dormitory of schools.
- Prefabricated huts or shelters can be used during promotion campaigns to clearly demonstrate how to install the LN's (e.g. to keep the mosquitoes and other insects out, be sure to tuck the bottom of the net under the mattress or let it hang so that it touches the ground all around).
- It might be important to provide nails and rope during distribution to facilitate the installation of the LN's.
- It might be important to replace old and damaged nets by new ones during the distribution.
- In malaria prone areas, make sure the net is used every night, even where mosquitoes are not heard or seen.
- Avoid using fire near the net or smoking under the net.
- It is often found that people use mosquito nets for fishing, clothing (wedding dresses) or for crop protection; be aware of this possibility when distributing nets and include this in the promotion campaign messages in order to avoid these practices.
- In case a LN was used by a patient with a highly contagious disease (e.g. ebola), the LN should be destroyed as it cannot be disinfected; insecticides and chlorine are not compatible.
- Some bednets (LN's) need time (up to one week) to recover their insecticidal capacity after washing. This process can be accelerated with heat (e.g. put LN under a blanket in the sun for a day; the blanket is required as insecticides break down under UV radiation).

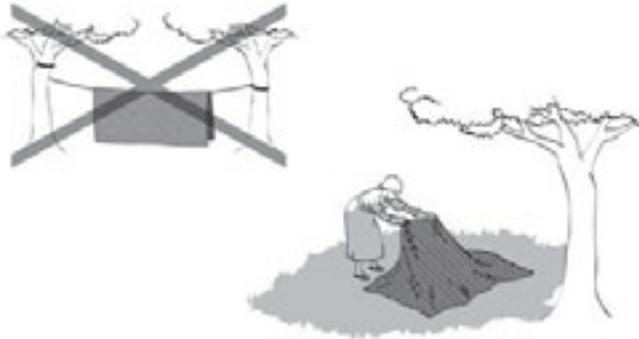
T.B. 7.17 Impregnation of nets, clothing and curtains

Using a net that is impregnated with public health pesticides is much more effective than using an untreated net. If a net is not treated, mosquitoes quickly find any body part touching the net or that is accidentally left uncovered. Insecticide treated nets inhibit mosquitoes, but also bedbugs, lice, fleas, sandflies, cockroaches from biting. Clothing and curtains can also be impregnated.

Principles

It is recommended to use a single pre-packed dose required for the impregnation of one net and its conversion into a Long-lasting insecticidal Net (LN). It is available as a kit, containing a single insecticide dose, a binding agent sachet, gloves, a plastic measuring container (or bag) and the impregnation instructions. It is usually more efficient to treat several nets at the same time using one dose per net treated. Used nets should be washed and dried before treatment. The following impregnation procedure can be applied to curtains and clothes as well. For the impregnation of clothes, the insecticide formulation needs to be identified with support of your technical referent (e.g. a formulation with deltamethrin as active ingredient will irritate the skin and is not at all appropriate).

- Collect the necessary equipment: basin or plastic bag, gloves, soap, net and impregnation kit (insecticide, binding agent, plastic measuring container or bag).
- Make sure the net is clean. If not, wash it with soap and water and dry it before impregnation.
- Choose an appropriate site to do the impregnation. It is best to treat the net outdoors in the shade. If you must treat the net indoors, do it in a room with open windows.
- Put on protective rubber gloves.
- Measure the correct amount of water in the measuring bag and pour it into the basin or plastic bag: 0.5 litre is required for a synthetic net (e.g. polyester or polyethylene) and 2 litre of water is required for a cotton net and this independent of the size of the net. If the net is exceptionally large or thick, some excess water might be required.
- Add the correct amount of binding agent, when available, to the water and stir thoroughly to mix.
- Add the correct amount of insecticide to the water. The amount of insecticide or “dose” needed to treat one net may come as a tablet, small bottle or sachet of liquid.
- Mix the water and insecticide thoroughly.
- Unfold the net and put it in the basin or plastic bag with the insecticide solution you have prepared.
- Soak the net long enough to insure that all parts of the net are impregnated.
- Lift the net and wring gently. Do not wring too hard - as when washing clothes - or the insecticide will be lost.
- Do not hang the net on a line, otherwise the insecticide will be distributed unevenly or even drip out. Spread the net out flat in the shade to dry. Do not leave the net in the sun as insecticides break down under UV radiation. Later, it can be hung up to finish drying.
- Use any leftover mix of water and insecticide to treat curtains. Otherwise, dispose of it in the latrine or in a specific hole, but away from ponds, rivers, streams, wells, springs, boreholes, the house or animal shelters. Never store the mix of water and insecticide.
- Wash the basin with soap and lots of water.
- Dispose of used gloves, plastic bags and empty insecticide containers (T.B. 7.12).
- Wash your hands with water and soap.

A**B****C****Key**

- A. Material needed for impregnation
 B. Impregnating the net
 C. Drying the net correctly
 1. Measuring container or bag
 2. Clean net
 3. Gloves
 4. Soap
 5. Basin or plastic bag
 6. Insecticide formulation
 7. Binding agent

Remarks

- An untreated mosquito net, if properly used and maintained, can provide a physical barrier to hungry female mosquitoes. Biting is still possible if there is a small tear in the net, if the net is not covering the entire bed or if part of the body is touching the net. If treated with insecticide, net effectiveness is greatly improved, generating a chemical halo that extends beyond the mosquito net. This tends to repel mosquitoes from biting or shorten their lifespan and reduce malaria transmission. Even a treated net with holes will have this impact as the mosquito will have to be in contact with the net to locate the hole.
- The use of LN is recommended (T.B. 7.16). LN's are ready-to-use factory pre-treated nets. Long-lasting insecticidal Nets retain their insecticidal properties for two to five years, the physical lifespan of the net. A LN only needs re-treatment after 20 washes. As a consequence, and if used in a normal way, they do not require further treatment during their normal life.
- In health structures, nets should be washed when stained (e.g. blood, excreta, vomit) or at least at regular intervals (e.g. each month). In this particular case, LN's will be washed 20 times after almost two years period, thus before the end of their lifespan. If the LN's are still in good condition at this moment, they need to be re-impregnated prior to being used again (T.B. 7.17).
- Re-impregnation of LN's is also necessary when information on when they were installed in the health structures and how many times they were washed is not available (T.B. 7.17).
- Use only public health pesticides that are recommended for mosquito nets impregnation. A wettable powder formulation cannot be used for net treatment. As the net dries, the wettable powder no longer adheres to the flexible fibres and falls down. A person using the net risks inhalation and accumulation of insecticide on the exposed skin during the night.
- If a concentration exceeding the recommended dosage is used, people may experience eye or skin irritation when sleeping under the net.
- Direct skin contact with the insecticide on a net that is still wet may cause a tingling sensation of the skin and is best avoided.
- After treatment the net may slightly smell of the insecticide. The smell will go away in a few days and is not harmful to people who sleep under the net.

T.B. 7.18 Insecticidal dusting

An insecticidal dust consists of talcum powder, or another inert carrier powder, mixed with insecticides. They are most useful for the treatment against rat fleas as well as human fleas, body lice and ticks. They can be applied with dusters between the body and the underwear or in hollow walls, false ceilings, or other hiding places that cannot easily be reached. The dust disperses well and can penetrate deep into cracks and crevices.

Principles

Rat fleas

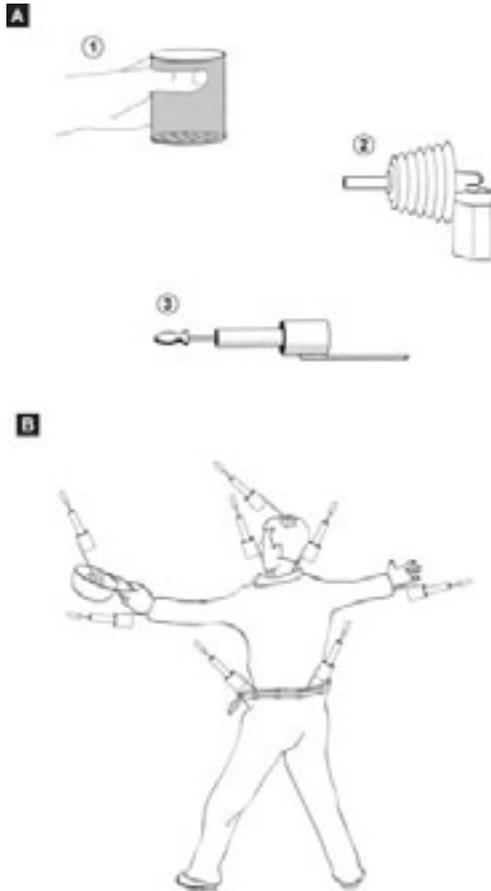
- Apply insecticidal dust against rat fleas a week earlier than rat poisons during the control of urban outbreaks of plague. This is to prevent fleas from moving to humans when the rats are killed.
- Apply insecticidal dust to burrows, runways and other sites where rodents are likely to pick it up. When the rodents groom themselves, they spread the dust on their fur, thus killing the fleas. Before control is begun, it is important to know where rodent burrows and runways are. To save insecticide, the burrows should first be closed off; only those that are subsequently re-opened by the rat should be treated.
- Blow insecticidal dust into each burrow with a duster. A 1 cm thick layer of dusting powder should be left around the opening.
- Deposit patches of dust that are 15 - 30 cm wide and 1 cm thick along runways.
- Apply dust only where it will remain undisturbed by humans, wind or rain. Insecticidal dust remains effective for 2 - 4 months if used in undisturbed dry places.
- Do not apply dusts to wet surfaces as this reduces their effectiveness.
- Apply dust only when the sprayed surfaces have dried, when used together with residual spraying (T.B. 7.15).

Human fleas

- Dust mattresses, beds and crevices in floors where the fleas rest during the day.
- Use a dust that does not cause irritation when in contact with the body. Dusts with a maximum of 1% of permethrin, as the active ingredient, are recommended. Ready to use preparations are the safest and recommended option.
- Pay attention to the type of talcum used in the formulation; some are only for use on animals and some are cleared specifically for human use.
- Do not treat infant bedding with insecticidal dust, but wash them thoroughly and regularly instead.

Human body lice

- Apply about 30 - 50 g of powder over the surfaces of clothing that are in close contact with the body for individual treatment. Powder is applied to the fully clothed subject at the neck, half at the front and half at the back, then spread by rubbing to ensure complete coverage. Pay specific attention to seams of underwear, sleeves and socks if they are worn. Make sure the powder is applied in a cultural sensitive manner, especially between the skin and underwear. Leave it for 12 to 24 hours. This is the preferred method for mass treatment.
- Do not dust open wounds (e.g. scratching related to scabies).
- Treat headwear, additional clothing, blankets and bedding as well (e.g. add about 30 - 50 g of powder to a plastic bag containing the additional set of clothing).
- Make hand shakers by puncturing one end of a can (approximately 2.6 holes/cm² and of 3 mm diameter). Application with a soup spoon is also simple and practical; 1 soup spoon is about 15 gram: use one at the front and one at the back.
- Apply only dusts with a maximum of 1% of permethrin as active ingredient. Ready to use preparations are the safest and recommended option.
- Pay attention to the type of talcum used in the formulation; some are cleared specifically for human use but some are only for use on animals.
- Dust patients before being admitted to a health structure as every bout of fever or large drop in temperature (e.g. death) promotes the movement of lice to a new host.
- One treatment should be sufficient but re-treatment might be needed at intervals of 8 - 10 days if infestations persist.



Key

- A. Devices used for insecticidal dusting
 B. Treatment of human body lice with insecticidal dust
1. Hand shaker
 2. Puff dusters
 3. Plunger type duster

Remarks

- Take care not to apply public health pesticides where they can contaminate food or where children might be playing.
- When dusting people, be sure to explain the purpose since the insecticidal powder leaves visible traces on the clothing.
- Ready to use dusting formulations are the safest and recommended option. Contact your technical referent in case other options are considered.
- A combined rodent and flea control, using baited traps is possible using baits that combine insecticide and rodenticide characteristics. After bait ingestion, the flea will die first due to the insecticide that will diffuse through the rodent's skin; the rodent will die later due to the rodenticide. This strategy can be interesting in case of plague or murine typhus outbreak. Contact your technical referent in case this option is considered.

T.B. 7.19 Rodent control

The most important methods to reduce the rodent population are mechanical protection, sanitation, traps and poison. Often a combination of these methods is needed to achieve a significant decrease of the rodent population. Complete eradication remains very difficult as only a limited area is targeted with rodent control. The control campaign should be accompanied by health promotion.

Principles

Mechanical protection

The aim is to prevent access to rodents to important or vulnerable areas:

- Block or protect all openings greater than 6 mm with cement or metal netting (1 mm wire, mesh less than 6 mm diameter).
- Fit barrier (e.g. discs) on cables that join roofs.
- Paint a smooth band (oil painting) of at least 30 cm wide on walls, at 1 m from the ground, to prevent passage on rough vertical surfaces.
- Fix galvanized sheets (1 mm thick) at the bottom of doors and on skirting.
- Pay particular attention to warehouse management (e.g. recondition where required, clean regularly).

General environmental sanitation

The presence of food sources and shelter in areas of human habitation attracts rodents and could be associated with outbreaks of plague. General environmental sanitation and proper household hygiene can do much to reduce any type of rodent infestation, more specifically:

- Limit access of rodents to food supply (e.g. harvest fruit in a timely manner, make it possible to store all food in rat-proof containers).
- Install a proper disposal of food residues and refuse.
- Eliminate or at least reduce the protective vegetation cover that is crucial to the rodents. Prune shrubs so that the ground below them is clearly visible. Mow, trim or remove ground cover plants. Stack firewood, lumber and other materials at least 30 cm away from walls and fences and at least half a meter above the ground.
- Keep irrigation and drainage canals clean.
- Avoid, where possible, access to any source of water during hot dry weather. This unless you want to attract and trap them.

Traps

- Traps can be divided into three types:

→ Spring traps: can be efficient but not to be used in the vicinity of children or non-targeted animals.
→ Cage traps: allow to catch the rodents (alive for observation or examination if needed).
→ Rat glue is available in tubes and should be put on a piece of cardboard with some bait in the middle.

- Keep in mind that rodents are very suspicious, always use the same runs and learn very quickly. This means that traps should be used in large numbers, over a short period, on carefully chosen sites, perpendicularly to rodents runs. It is also best to leave the traps not set for a few days after installation to reduce trap shyness.
- Check traps twice a day to remove captured rats and replenish bait if required.
- Do not place glue boards where children, or other non-targeted animals might be in contact with them. Replace glue boards often; they lose their effectiveness when covered by dust or insects. Effectiveness is also reduced by heat and moisture, therefore it is recommended that glue boards be used only indoors.

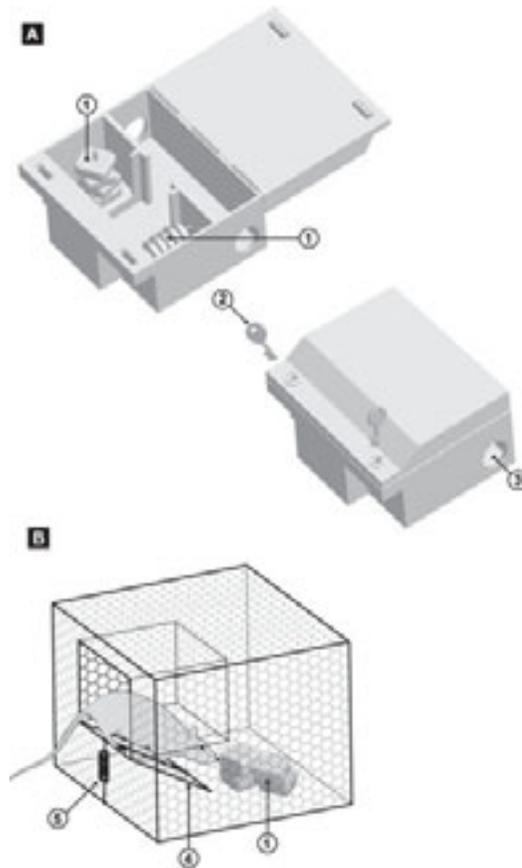
Rodenticides

Rodenticides can be divided in two classes:

- Chronic or slow-acting rodenticides: referred to as multiple dose anti-coagulants that are the safest for the user and generally require several doses (e.g. Difenacoum Brodifacoum, Bromadiolone, Difethialone). They are normally the first choice rodenticides and exist in different formulations

(e.g. grains, blocks, paste, gel). Their advantages are that they don't cause bait-shyness, and accidental poisoning of people or animals is unlikely to happen. Some formulations are weather resistant. However, rodents can become resistant to them and before selecting the rodenticide, information on local resistance should be collected.

- Acute rodenticides such as zinc phosphate, arsenic oxide and Fluoroacetamide are mainly for industrial applications (e.g. ships). They are very toxic for human beings and are not recommended for general use. They are effective in situations where anticoagulant resistance exists and where the dead bodies can easily be found and disposed off. However, it is advised to use these products only if you have no other option because of the health risks that they represent to man and non-targeted animals. Such intervention can only be envisaged after discussion with your technical referent.



Key

- A. Temper resistant bait box with key and bait
- B. Metallic cage trap
- 1. Bait
- 2. Key
- 3. Entry / exit
- 4. Trapdoor
- 5. Spring

Remarks

- Against a flea-borne disease (e.g. plague or murine typhus), the flea control must precede rodent control to prevent fleas from moving to humans when the rats are killed. If not, the spread of these flea-borne diseases can be encouraged (T.B. 7.18).
- All rodenticide containers should be clearly marked with warning labels and stored securely.
- A health promotion campaign to enlist the help of the community groups and individuals is probably the most essential component of the rodents control activities.
- Rodenticides can be very effective, but their use requires supervision and follow-up by well-trained staff.
- Before placing any bait, check that rats are not a supplement to the diet of the population / refugees. If this is the case contact your technical referent. In any case, inform the population about the control campaign and the risks of the rodenticides.
- Temper resistant bait boxes are bait boxes that can be closed with a key. These boxes should be secured to the ground, so the population cannot take and use them for other purposes like storage of food. They represent a safe way to place baits, in opposition to PVC or bamboo that are commonly used but that still allows access to the bait by children.
- Prior to embarking on a rodenticide campaign, limit the rodent access to food supply and nesting places. As long as this is not taken care off, the rodent population will grow and quickly reach its former population level. The impact of a rodenticide campaign will in this case be negligible.
- Rat control activities using ultrasonic sounds to scare the rats away are not recommended.
- Offering rewards to bring in rat tails as proof for each killed rat has previously shown to be contra productive as it resulted in people breeding rats.
- Particular attention should be paid to protecting vulnerable refugees (such as the old and the sick) from being bitten by rats. Those suffering from leprosy may be especially defenceless when sleeping due to their lack of sensations in fingers and toes.
- Rodenticides can be used in health structures and warehouses but are generally not recommended for use in refugee camps. The large number of children, having little to do and few things to play with, make it risky to place poison bait traps around the camp environment.
- For safety reasons, utilise pre-packed ready to use rodenticides already mixed with baits.
- Bait must not be placed haphazardly. Care must be taken to place the bait where the rodent will find it, but children and animals cannot.
- Check baits twice a day for replenishment of bait.
- Care has to be given to correct collection and disposal of carcasses: put dead rats safely in a plastic bag and bury them in a deep pit.
- Caution to safe handling of trapped rodents (e.g. the multi-mammate rat is the natural reservoir for the Lassa fever virus; the virus is spread through the urine of the rats; if trapped, these rats urinate wildly and become covered with the virus; their corpse must be disposed of without direct contact).
- Impact of rat control can be observed after 3 weeks for the brown rat, and 4 to 5 weeks for the black rat / mouse.

T.B. 7.20 Protective Clothing

All public health pesticides are toxic to some degree. Absorption can occur through contact (skin), inhalation (lungs) and/or ingestion (mouth). Specific protective clothing must be worn in accordance with the safety instructions on the product label.

Principles

General Insecticide Use

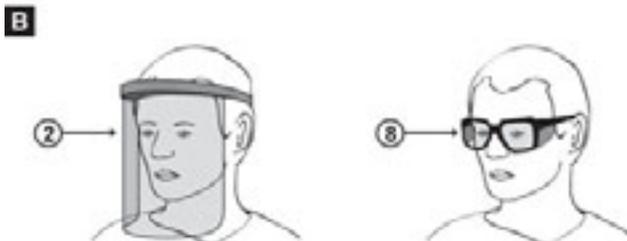
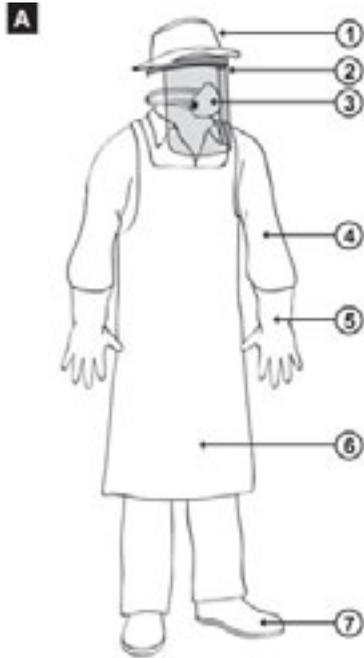
Even for apparently straightforward application of public health pesticides (e.g. placement of cockroach poison, impregnation of fabrics), a minimum of protective clothing is required.

Spraying / Dusting / Packing

During spraying, dusting or packing activities, absorption of insecticide can occur through contact, inhalation and/or ingestion. Therefore specific protective clothing must be worn, covering all parts of the body.

Care and Use of Protective Clothing

- Wash clothing daily. Keep it in good state of repair, and inspect it regularly for tears or worn areas. Keep clothing in a closed, ventilated place, out of the reach of children.
- Take the clothes off immediately after the work is finished and do not take them home. Protective clothing should be changed if it becomes wet. As such, a spare set of protective clothing is useful on the field.
- Change the respirator every day. The respirator prevents exposure of the face (protects nose and mouth from airborne particles of the spray) and inhalation of vapour.
- Protect head, face and neck from spray droplets by a broad rim hat.
- Wash face shield or goggles regularly to maintain visibility. Face shield or goggles protect the eyes from drops of insecticide.
- Wear an overall, even when hot, to protect the body and wash it regularly. Wear clothing under it (e.g. underwear, T-shirt).
- Wear boots to protect the lower legs. The overall pants should be tugged over the boots.
- Wear plastic gloves to protect the hands when handling and spraying the insecticide. The sleeves of the overall should be tugged within the gloves. After use, the gloves should be rinsed with water before they are taken off. They should be washed daily with soap, separately from other clothing. Gloves should be washed on the inside as well. Be careful when re-using gloves not to wear them inside-out.
- Provide access to good washing facilities (after the job is done) to personnel involved in chemical vector control.



Key

- A. Protective clothing for Insecticidal Residual Spraying
 B. Face / eye protection

1. Broad rim hat
2. Face shield
3. Face respirator
4. Long sleeved overall (keep the overall outside of the boots).
5. Long rubber gloves (keep the overall inside of the gloves)
6. Rubber or plastic apron.
7. Boots.
8. Safety glasses

Remarks

- Use public health pesticides safely (T.B. 7.13).
- The quality of the respirator should be adapted to the public health pesticide and formulation used, and needs to be verified with your technical referent (e.g. minimum FFP2 for pyrethroids, minimum FFP3 for carbamates).
- Depending on the situation, a centralized system of storage and care may be the best option with protective clothing handed out prior to the control activity and collected and cleaned afterwards. This ensures better control and care of the equipment.
- A face shield is the preferred option for full face and eye protection. They are less hot to wear and do not mist over as easily as goggles. If no face shield is available, a pair of safety glasses is an acceptable alternative.
- Protective clothing can be a mayor source of exposure to operators if it is not either carefully washed or disposed after use.
- In hot and humid climates, wearing of protective clothing may be uncomfortable and the sweat generated increases absorption of insecticide. Public health pesticides should therefore be applied during the cooler hours of the day, to minimize neglect of the safety rules and assure use of protective clothing. It is the responsibility of supervisory staff to ensure that the appropriate protective clothing is worn, no matter what the circumstances.
- If poisoning is suspected, medical help must be sought immediately. Some indications of insecticide poisoning are: extreme weakness and fatigue, skin irritation or burning sensation, itching eyes, nausea, vomiting, diarrhoea, headache, cough, chest pain, unconsciousness (T.B. 7.13).
- Overalls should be available in two samples to allow a daily washing and drying, even in tree samples in particular circumstances like during rainy season or under humid climates where it takes more than one day to dry.

Disposing of Dead Bodies

Narrative

Technical briefs

T.B. 8.01 Special precautions when disposing of dead bodies

T.B. 8.02 Morgue

T.B. 8.03 Cemetery

T.B. 8.04 Cremation

Chapter 8

8.1 Why disposing of dead bodies?

It's a common misbelieve that dead bodies who are not or cannot immediately be dealt with would lead to epidemics. Dead bodies related to war, famine or natural disasters do not form a direct and immediate public health risk. So this misbelieve should not be transmitted to the affected population because it will only increase their traumatic experience. Still, it's advisable to deal with the corpses as soon as possible because of:

- The respect that should be paid to the population's culture regarding the deceased.
- The proximity of the dead bodies, often after a traumatic experience, can lead to mental health problems of the survivors. But the unceremonious disposal of the corpses, can have the same impact as well.
- The nuisances such as the odours.
- The scavengers and vectors that will be attracted and can represent an indirect health hazard.

However, deceased victims of cholera, plague, typhus and viral haemorrhagic fevers (e.g. Ebola, Marburg), can have an impact on the spreading of the respective disease to a wider population and thus can represent a direct health risk. Rapid and special precautions have to be taken when disposing of these kinds of dead bodies. An in-depth description of how to deal with deceased victims of these diseases can be found in the respective guidelines (section 8.5 Further reading).

8.2 What is disposing of dead bodies?

Disposing of dead bodies can include locating the deceased, collection, preparing the body for viewing (with possible disinfection of the body and the living environment of the deceased; T.B. 8.01), registration, body dressing (e.g. putting body in a coffin), transport (with potential disinfection of the means) and burial or cremation.

In general, the culture and wishes of the relatives should be respected as much as possible, as this helps the survivors in their mourning process. But particular rules (e.g. rapid burial) have to be respected for the casualties of specific diseases as described hereunder (T.B. 8.01 and section 8.5 Further reading) as they can lead to epidemics. It is of utmost importance that correct information concerning the risk of being in contact with deceased of highly infectious diseases is well explained to the relatives and the neighbours, otherwise they might be reluctant to bring the sick people to the health centres.

8.3 Where and When should dead bodies be disposed of and by Who?

It is obvious that dead bodies should always be dealt with, as soon as possible. It should be strongly encouraged that the relatives take responsibility themselves for the dead body, in case the deceased is a victim of war, famine or a natural disaster. This can be done according to their usual cultural and religious procedures, such as the preparation for viewing of the deceased and body dressing. Those steps are often done at home. They have a positive influence on the psychological and emotional effects of the relatives, as they are essential steps in the mourning process.

However, the aid-agencies will often have to provide adapted funeral areas:

- Morgue (should be available in all in-patient health structures, and sometimes there is a need for additional ones after natural or man-made disasters (e.g. war) due to the high number of casualties, or in isolation centres dealing with specific diseases (T.B. 8.02).
- Cemetery (T.B. 8.03) or cremation site (T.B. 8.04).

These facilities have to correspond to certain specifications. The sites need to be chosen in collaboration with the local authorities and preferably as well with the affected communities.

The aid-agencies can also help the affected population in providing shrouds and/or transport if necessary. In particular contexts (e.g. high number of dead bodies after a natural disaster), the aid-agencies might have to collect and dispose of the deceased.

The role of the (medical) aid-agencies in disposing of dead bodies increases in importance during the control of an epidemic of highly infectious diseases. For viral haemorrhagic fevers for instance, the preparation of the dead body (e.g. disinfection of the body and leak proof body bag) has to be taken in charge by a trained team (T.B. 8.01) in order to avoid further spreading of the epidemic. In such a context, it is important to promote and supervise safe burial, and possibly to disinfect the living environment of the deceased.

8.4 How to dispose of dead bodies?

Follow up on identification of the deceased, information towards their relatives, human rights and legal issues are very important, but fall outside the scope of these guidelines (section 8.5 Further reading).

During epidemics of highly infectious diseases, the dead bodies will have to be disposed of with specific precautions. In all other cases, it isn't necessary and even not advised to disinfect the corpses. Dead bodies that can't be removed immediately (e.g. corpses left on the street due to insecurity conditions) can be covered with lime. Since the high pH of the lime "disinfects" to a certain extent the dead body superficially, but doesn't affect internal pathogens, its effectiveness is limited. However, lime can reduce the odour of the corpses that start to decompose.

Special attention should be paid to the protective clothing of people coming in contact with dead bodies having open wounds, or deceased victims of highly infectious diseases as described in the respective guidelines. In all other cases, the relatives that deal with the dead bodies don't require any specific protective clothing. However, it is recommended that all people that have been in contact with dead bodies do wash themselves thoroughly with water and (preferably antiseptic) soap.

Whereas the traditional funeral rites and practices are important for the relatives (e.g. mourning process), they should be adapted for victims of highly infectious diseases as they could lead to the further spreading of an epidemic. Supervised funerals together with other safety procedures to avoid further spreading of the specific disease should also be addressed in the obligatory health promotion campaign.

Besides cloths, coffins are often used as well to bury the dead bodies. In case of acute emergencies, those items are often not available in sufficient numbers, thus blankets or mats or preferably appropriate body bags can be used as an alternative. In epidemics of highly infectious diseases, it is strongly recommended to use leak proof body bags (in addition to a coffin).

In most cases, the body is carried by the relatives in procession to its final resting place. However, in epidemic situations, it might be necessary for the aid-agency to do the transport of the deceased person. It is very important to disinfect properly the vehicles used for transporting the infectious corpses, according to the existing standards per specific disease (section 8.5 Further reading).

In general, the preferred final step is burial in a cemetery as it is simple and cheap. However it does require a lot of space (foresee about 1500 m² for a population of 10.000 persons; T.B. 8.03). If possible, individual burial should be chosen over mass graves, to allow the relatives to visit the actual tomb of the deceased person. In certain cultures, the corpses are embalmed before they are transported to their final resting place.

If not specifically demanded by the relatives, it is strongly advised not to cremate the dead bodies, and certainly to avoid mass cremation (T.B. 8.04), not even the corpses of highly infectious diseases. Cremation will require enormous amounts of fuel. Often, the cremation will succeed only partially, especially if experienced and skilled personnel is lacking to perform this task. The smoke generated during the cremation can be hazardous to health as it contains dioxins and possibly thermo-resistant pathogens.

8.5 Further reading

Médecins Sans Frontières

Cholera guidelines

Médecins Sans Frontières, 2004

PAHO/WHO/IFRC/ICRC, Geneva

Management of dead bodies after disasters: a field manual for first responders

ICRC Publication, 2006

P. Harvey, S. Baghri, B. Reed

Emergency Sanitation

Water, Engineering & Development Centre (WEDC), 2002

Médecins Sans Frontières

Filovirus Haemorrhagic Fever

Médecins Sans Frontières, 2007

T.B. 8.01 Special precautions when disposing of dead bodies

In most cases, no special precautions beyond normal hygiene practices are required when disposing of dead bodies. However, specific precautions are required if people died from highly infectious diseases. These precautions may include amongst others the wearing of protective equipment, the disinfection of the dead body and the restriction of traditional funeral practices. Nevertheless, in every circumstance, all efforts must be made to ensure that the body is treated with respect and in a dignified manner.

The following table shows precautions recommended for the highly infectious diseases likely to be encountered in the field.

Precaution	Cholera	Ebola Marburg	SARS	Typhus Plague	Tuberculosis	HIV/AIDS
Wearing of specific protective equipment	<ul style="list-style-type: none"> • Yes • rubber gloves • overall • apron • (rubber boots) • goggles • (protection against chlorine splashes) 	<ul style="list-style-type: none"> • Yes • respirator • FFP2 • goggles • double rubber gloves • gown • head cover • rubber boots • apron 	<ul style="list-style-type: none"> • Yes • respirator • FFP2 • goggles • rubber gloves • gown • head cover • rubber boots 	<ul style="list-style-type: none"> • Yes • rubber gloves • overall • apron • respirator • FFP2 (if pneumonic plague) 	<ul style="list-style-type: none"> • Yes • rubber gloves • respirator • FFP2 	<ul style="list-style-type: none"> • Yes • rubber gloves
Body disinfection (with chlorine solution)	2%	0.5%	0.5%	No	No	No
Insecticide dusting of body and clothing	No	No	No	Yes	No	No
Blocking body orifices	Yes	No	No	No	No	No
Body bag (or similar)	Yes	Yes	Yes	Yes	Yes	Yes
Immediate burial (within 12 hours)	Yes	Yes	No	No	No	No
Limitation of funeral gatherings	Yes	Yes	Yes	No	No	No
Promotion of safe funeral practices	Yes	Yes	Yes	Yes	No	No
Supervised funerals	Yes	Yes	No	No	No	No
Disinfection of the living environment of the deceased	Yes	Yes	Yes	No	No	No

Remarks

- In the case of body disinfection, it cannot be considered as a complete disinfection of the body because it still contains pathogens. Nevertheless, it temporarily improves safety when transferring the body to the (leak proof) body bag or while wrapping it in plastic sheeting.
- It is recommended that blocking the orifices in the case of cholera is performed by a (para-) medical person.
- Use of (leak proof) body bags is recommended for all infectious diseases.
- Supervised funerals have to be considered when traditional funeral practices are particularly risky for the health of the family, the neighbours and the community.
- When bodies that have started to decompose must be collected, spraying an insecticide and chlorine solution around the body and on surrounding leachates (if present) might be useful. It can be done inside a house or a building, but also outside, in an open place.
- To avoid the occurrence of rigor mortis in an undignified position, always dress the body properly as soon as it is noticed that the person passed away.

T.B. 8.02 Morgue

All health structures who have patients staying overnight should possess a morgue. But it might also be necessary to set up a morgue in case of an emergency like an epidemic, a natural or a man-made disaster (e.g. war) where a lot of people have died or will die. When needed, a morgue has to be foreseen from the beginning (e.g. onset of an emergency).

Construction

- Inform yourself well with the local population and medical staff on the customs and cultural aspects related to death. They will be able to give you information on how a morgue should look like, how long the deceased will stay in a morgue, how the relatives will collect the dead body.
- Look for a place within the “technical” zone of the health structure, close to the fence with a specific exit for the morgue. This enables the relatives to view and collect discretely the deceased person, without creating an uneasy feeling for other patients and visitors of the health structure.
- Fence the area well to avoid unauthorised people to enter. Foresee also some additional space for potential (temporary) extension of the morgue (e.g. during emergencies).
- Include within the morgue facility:
 - a space (quite and peaceful) where relatives can wait and mourn (this can be outside the morgue, but preferably shaded in hot countries).
 - some space where the register files and personal belongings of the deceased can be stored.
 - a room where the deceased can be prepared and possibly be viewed by the relatives. For small health structures (e.g. about 20 beds), a capacity for 1 or maximum 2 dead bodies is sufficient. For bigger health structures, the capacity should be determined with the medical staff.
- Avoid windows in the actual morgue building. Ventilation holes in the upper part of the walls protected by grills to avoid rodents to enter are more appropriate.
- Cover the floor with smooth concrete in such a way that it has a slope of 1% leading towards a drain. This enables the evacuation of wastewater and body fluids via a grease trap towards an infiltration system (chapter 4). Make sure that small animals can't enter the drain pipe that leads the wastewater outside.
- Provide masonry tables in chronic emergencies and stabilised situations to avoid having to put corpses on the ground. To keep these tables clean and hygienic, it's recommended to cover them with ceramic tiles. The tables should present a gentle slope towards their centre and a channel allowing to drain body fluids and wastewater in a bucket.
- Foresee a plastic curtain in between the tables to permit some privacy when relatives come to view the deceased.
- Install a light inside the morgue for safety / security reasons.
- Provide a water point close to the morgue (< 20 m) for body disinfection and washing, according to local customs.

Remarks

- In the very first phase of an emergency, a tent is often used as a morgue. It should be replaced as soon as possible with a temporary semi-hard structure to better protect the dead bodies against the adverse climatologic conditions, vectors such as rats, scavengers and looters. The lower part of the building should be in bricks or reinforced with metal plates when the structure is completely in wood. The floor should be in concrete.
- The morgue should be part of the whole health care infrastructure, in order to be guarded as the rest of the facilities.
- Only authorised persons should have access to the morgue.
- The morgue should be kept clean and be disinfected regularly with a chlorine solution (T.B. 2.20).
- In case storage is essential, the dead bodies should ideally be kept at a temperature of 4 °C, but this is hardly possible in a lot of low-income countries as it creates a lot of logistical constraints.
- In hot / low-income countries, dead bodies will often be buried / cremated within 24 hours, therefore special rooms to store the deceased are mostly not needed.
- In case there isn't a cold storage place and the family or the caretaker has not collected the deceased after more than a day, the body should preferably be buried / cremated promptly by trained staff, according to the specific context (e.g. special precautions in case of an infectious disease, otherwise according to the normal funeral rites). However, the identity of the deceased should be known, or at least a picture should be taken before the funeral takes place, in order to provide information towards the relatives.

T.B. 8.03 Cemetery

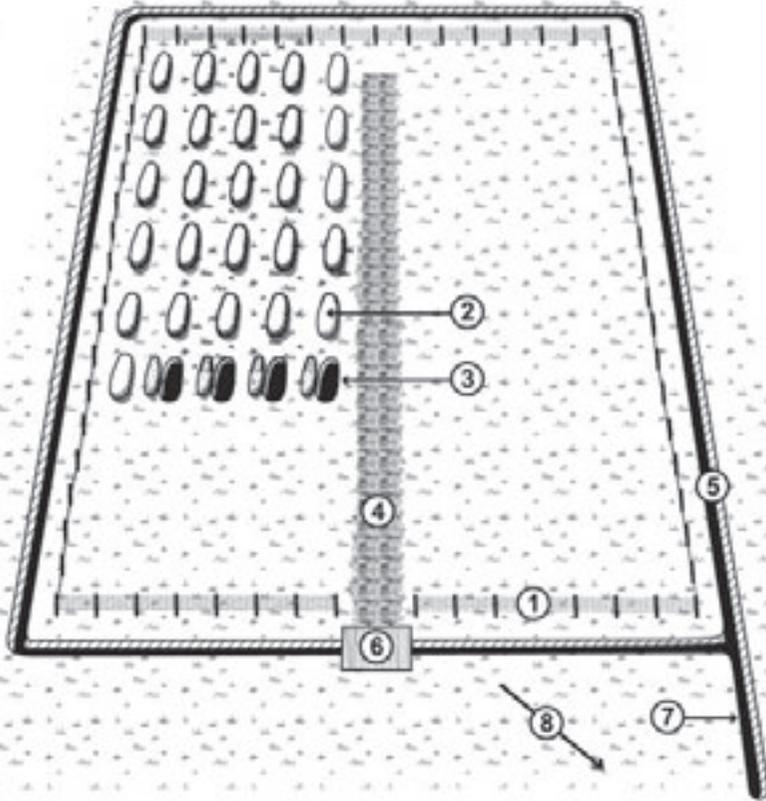
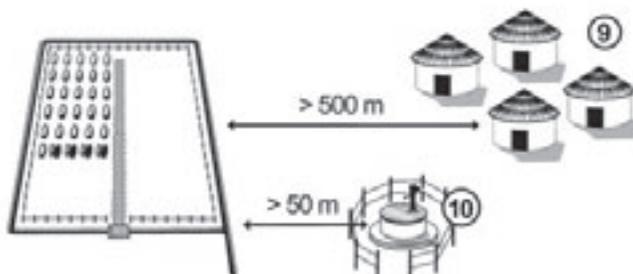
Unless another solution / procedure is specifically requested by the relatives, burial is the preferred method of final disposal of dead bodies. A cemetery has to be foreseen from the beginning (e.g. onset of an emergency). However, burial requires sufficient land surface that has to respond to specific criteria.

Construction

- Calculate the minimum cemetery surface needed based on the population data:
about 1500 m² for a population of 10.000 persons
- Choose an area at least 500 m away from the dwellings. Take care about the distance from water points, which should never be less than 50 m and which should be uphill from the burial site. The water table at its highest level (at the end of the rainy season) should be at least 3 m deep. The selection of the site has to be done in collaboration with the local authorities and preferably also with the host and the affected population.
- Fence the area well to avoid people to install their dwelling within.
- Make a central alley and potentially pathways in between the rows of the (future) tombs.
- Dig a drainage ditch around the whole area to avoid runoff water eroding the soil away from the graves. This ditch should lead towards a drainage canal to evacuate runoff water that doesn't infiltrate during heavy rainfall.
- Construct a ditch crossing at the entrance of the cemetery for easy access.

Operation

- Dig preferably individual graves for the relatives to be able to visit the tomb of the deceased person. The orientation of the grave might in certain cultures be important as well. The grave should be at least 1.5 m deep, and the bottom should be at least 1.5 m above the highest water table to avoid its biological contamination (if the soil is homogenous).
- Leave the burial ceremony up to the relatives according to the local cultural and religious rituals as this helps them in their mourning process, unless the deceased was victim of a highly infectious disease. In the latter case, the burial has to be supervised by trained and experienced personnel, complying as much as safely possible with the local cultural and religious rituals.
- Make sure that the dead body is covered with at least 1 m of soil. This depth is important to avoid bad odours and dogs or other carrion-feeders digging out the corpses.
- Keep the cemetery tidy (no waste laying around, vegetation kept under control) and dignified.

A**B**

Key	Input
A. Cemetery	
B. Minimal safety distances	
1. Fence	<i>Construction</i>
2. Used graves	- Land (1500 m ² /population of 10.000 persons)
3. Reserve graves	- Stakes and fencing material
4. Alley	- Poles or tree trunks to build a bridge over the drainage ditch
5. Drainage ditch	- Shovels, hoes and pick axes to construct the ditch
6. Ditch crossing	
7. Lowest corner towards infiltration facility with overflow	<i>Operation</i>
8. Runoff direction	- Mechanical shovel or numerous workers
9. Dwellings	- Shovels, hoes and pick axes
10. Well	- Trained personnel, permanently at the cemetery
	- Protective clothing for the personnel

Remarks

- Burial needs a lot of land, but is otherwise rather simple and cheap.
- It might be necessary to foresee several cemeteries, or at least split up the graveyard in different zones when different religions and/or ethnic groups are living together.
- The bottom of the graves must be more than 1.5 m from the aquifer to avoid microbiological pollution of the groundwater by the corpses. The depth of the water table can be estimated by verifying its level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe into the ground, as deep as 1.5 m beneath the required depth of the grave. When pulled out, the rod or (the earth inside) the pipe should be dry. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level.
- Normally, it isn't necessary to line the graves. However in unstable undergrounds, it is recommended to install a removable (wooden) rectangular support until the body is lowered in the pit. This support which should avoid collapse of the upper soil layer should have the size of the hole and a height of at least 0.5 m within the edge of the grave.
- It's recommended to always have some graves dug in reserve but not too many at once because they will collapse over time. The Crude Mortality Rate indicates how many graves per day should be available.
- In acute emergencies when the Crude Mortality Rate is high, it might take too long to dig individual graves. Long trenches (possibly made with a mechanical shovel) where the dead bodies are put head to toe can be a solution, as it still permits to put an identification on each grave and thus the relatives visiting their deceased family member. However, try to avoid as much as possible mass graves with different bodies being piled up on top of each other, because visiting a deceased person is part of the mourning process for the relatives.
- Be assured that the coffin is well closed (and the lid well fixed) so that an accidental event during transportation or burial doesn't result in the body dropping out.
- Provide the possibility for the relatives to collect a piece of (white) cloth to cover the deceased person.
- Be aware that in some cultures the dead bodies are buried in a standing up or sitting position. Get information on the practices prior to the ceremony.
- In big catastrophes, with lots of dead people, it might be up to the aid-agency to do the burial of the dead bodies. Also in epidemics such as cholera, Ebola or Marburg, it is recommended to have a trained team who can do the (supervision of the) burial after the disinfection of the corpse and laying it in a leak proof / sealed body bag, in order to contain the disease.
- A fence and preferably guards are strongly recommended to guarantee the correct use of the cemetery. During emergencies, the guards should also act as graveyard watchers who count and report every day the new tombs.
- A maintenance team will be needed to dig new tombs and to keep the cemetery tidy. Depending on the size of the graveyard, this task can also be done by the guards.
- Make sure that the potential gate of the cemetery is open when a corpse arrives.
- Protective clothing should be available for the staff working at the burial site.
- Washing (at least water and soap) and related wastewater facilities should always be available onsite.

T.B. 8.04. Cremation

Cremation should only be considered if it is specifically requested by the relatives, because it's their tradition or preferred option. This technique is difficult and expensive and may cause health hazards. If this is a common option, a cremation site has to be foreseen from the beginning (e.g. onset of an emergency).

Construction

- Inform yourself well with local people experienced in cremation. They will be able to give you detailed information on cremation, the site, the facilities and the equipment that are needed.
- Choose an area at least 500 m away and downwind from the dwellings. Take care about the distances from water points, which should never be less than 50 m away. The selection of the site has to be done with the local authorities, the people experienced in cremation and preferably with the host and the affected population as well.
- Fence the area well to avoid unauthorised people to enter or to install their dwelling. A guard is recommended who can also register the number of people that are cremated.
- Dig a drainage ditch around the whole area to evacuate runoff water towards a drainage canal.
- Construct a ditch crossing at the entrance of the cremation site for easy access.
- Foresee a potential disposal area for the ashes, according the local customs (e.g. spreading the ashes on a well identified area). In case (unburned) residues need to be buried, the bottom of the residues pits or trenches must be more than 1.5 m above the water table to avoid microbiological pollution of the groundwater. The depth of the water table can be estimated by verifying its level in nearby wells. Another option is to drive a metal bar such as a reinforcing rod or (several pieces of) ½" galvanized pipe into the ground, as deep as 1.5 m beneath the required depth of the "grave". When pulled out, the rod or (the earth inside) the pipe should be dry. Soil saturated with water after heavy rainfall might give a false impression of the actual water table level.

Operation

- Leave the cremation process, according to the local cultural rituals, completely over to experienced local people.
- Make sure that when potential unburned residues are buried, they are covered with at least 1 m of soil and respect the recommendations as described in the T.B. 8.03.
- Keep the cremation site tidy and dignified.

Remarks

- Cremation is NOT required to dispose of deceased victims of highly infectious diseases. When cremation is not specifically requested by the relatives, burial is still preferred.
- This technique needs a lot of fuel and is thus expensive. To cremate one body, at least 300 kilogram of firewood is required, which leaves a big strain on the local environment. If cremation is the chosen option when a lot of bodies need to be disposed of (e.g. after natural catastrophe), it is recommended to bring in the wood from another place where industrial "wood chopping" is done, or to choose another combustible if possible. This will allow to decrease the strain on the environment.
- As traditional cremation is done with limited means, potential thermo-resistant pathogens and hazardous gases containing toxic components such as dioxins will escape as well. The more bodies are cremated at the same time, the higher the concentration of hazardous gases. So mass cremation should always be avoided.
- It might be necessary to foresee several cremation sites, or at least split up the site in different zones when different religions and/or ethnic groups are living together.
- A fence and preferably guards are strongly recommended to guarantee the correct use of the cremation site.
- Washing (at least water and soap) and related wastewater facilities should be available onsite.
- Burial sites for the unburned residues might be needed.
- Only specialised staff should perform this task.
- A maintenance team is essential to keep the cremation side tidy.

Glossary

Absorption	Incorporation of one substance by another (e.g. of gas by a liquid, of a liquid by the soil).
Accumulation rate	Rate at which decomposed faecal matter builds up in a pit latrine, expressed in m ³ per person a year, and used for the calculation of the effective pit volume.
Activated carbon	Specially prepared powdered or granulated carbon, used in final treatment of drinking water by adsorption, particularly for the removal of dissolved (organic) pollutants which impart colour, taste and odours to water.
Adsorbent	Pollutants (being dissolved causing colour, odour or taste, or turbidity) sticking (adhering) to filter material with a (very) large specific surface (e.g. activated carbon).
Aerobic	A process taking place in the presence of oxygen.
Ampoule	Glass container containing a medicinal solution or powder.
Amputated limbs	Accidentally or surgically removed human body extremities (e.g. arm, leg).
Anaerobic	Micro-organism living in a place or a process taking place without oxygen.
Antiseptic	Substance that kills or inhibits pathogen development and is harmless when applied to living tissues (skin, mucous membranes).
Apron	1. Concrete surface surrounding the head of a well for protection and drainage. 2. Protective cloth worn over (working) clothing when dirty or dangerous tasks have to be performed.
Aquatic	Living in water, or related to water.
Aquifer	Porous water-saturated layers of sand, gravel or rock that can store water and are permeable enough to allow water to flow through them in useable quantities.
Arbovirus	Any group of pathogenic viruses transmitted to vertebrates by arthropod blood suckers (e.g. mosquitoes, ticks), responsible of producing arboviroses.
Arthropod	A jointed-limbed invertebrate animal with a segmented body and external skeleton, which includes insects, crustaceans and spiders.
Auto-Disable (AD) syringe (auto-blocking syringe)	A specially designed disposable syringe with a fixed needle that is automatically disabled by blocking its plunger after a single use. Used very often for immunization; e.g. Enlarged Program of Immunization (EPI) or in mass vaccination campaigns.
Available chlorine	Pure chlorine content of a chlorine-generating product, expressed as a percentage, in chlorometric degrees, ppm or mg/l (e.g. 65 - 70% for calcium hypochlorite; 1° = about 0.3%, 1 ppm = 1 mg/l = 0.0001% active chlorine).
Bacteria	Microscopic unicellular organisms that usually multiply by cell division, certain of which are disease-causing agents. However, some can also be of aid in pollution control by metabolizing organic matter or other pollutants in wastewater, oil spills, etc.
Bacteriological analysis	Identification of bacteria of the coliform group (E-coli and Thermo Tolerant coliforms) and/or other micro-organisms indicating contamination of drinking water by faecal material of warm blooded animals, including humans. Total coliforms are not a good indicator for bacteriological pollution of drinking water.
Biodegrading / Biological decomposition	Natural process of destruction of organic material by microbiological activity.
Biological cycle	Developmental stages or phases through which an organism passes in one generation.
Bleach	Chlorine-generating product (NaOCl) in a liquid form containing 4 to 15% of available chlorine. Less stable than the solid formulations. See also sodium hypochlorite.
Breeding site or grounds	The place where insects proliferate, where they lay their eggs and where the eggs hatch.
Burial / Burying	Action of covering with earth (e.g. refuse, dead bodies).
Calcium hypochlorite (Ca(ClO)₂)	Chlorine-generating product in granular form (also found as tablets) containing 65 to 70% available chlorine, made by reacting chlorine with calcium hydroxide. Also called HTH®, which is a brand name.
Candle filter	Candle shaped ceramic filter element (pore size: often 0,45 µm).
Carbon monoxide (CO)	A colourless, practically odourless and poisonous gas formed by incomplete combustion. Its toxic action is due to its strong affinity for haemoglobin, myoglobin, and cytochromes, reducing oxygen transport within the human body and blocking oxygen utilization.
Catchment	1. Part of the well below the water table which allows water to flow into the well. 2. The emergence zone of a spring where safe water may be collected.
Catchment ring	Perforated or porous cylinder sunk into the water table, through which water passes.
Cavitation	The formation of gas bubbles (water vapour) and their implosion on the blades of a pump impeller or on the gate of a valve; the implosion of these bubbles can be with such force that it can cause pitting or even destruction of the impellor or the valve.
Chemical analysis	Tests for the identification of undesirable or toxic chemical substances whose maximum permissible concentrations determine the potability of water, according to scientifically pre-determined levels.
Chemical waste	Residuals or remains that contain substances that can react, affect or interfere chemically with the environment (e.g. laboratory reagents, film developer, expired disinfectants, solvents).
Chlorinated lime	Chlorine-generating product (CaO 2CaOCl ₂) in powder form, containing 30% chlorine. Less stable than calcium hypochlorite.
Chlorine	Reactive element (Cl) with strong oxidizing power, used for (water) disinfection.

Chlorine demand	Difference between the amount of chlorine added to water and the total residual chlorine level after minimum 30 minutes, meaning the chlorine that is consumed during the disinfection process.
Cholera	Intestinal toxi-infection, strictly human, due to <i>Vibrio cholerae</i> infection.
Coagulation	Part of the treatment process where the negative electrical charge of the suspended particles in the water becomes neutral, due to the addition of a chemical or biological compound. This step will be followed by flocculation and potentially sedimentation and/or filtration.
Collection box	Construction for collecting liquids from different pipes to pass it in one pipe.
Combined Residual Chlorine (CRC)	That fraction of the chlorine that has been added to water, which is not consumed, nor is freely available in the water, but has combined with certain substances in the water.
Compost	Humus-like product produced by the controlled decomposition of organic matter; either night soil or sludge mixed with organic material rich in carbon (such as refuse or sawdust); and valued as fertilizer or mainly as soil conditioner.
Concrete ring	Short concrete cylinder for supporting and lining the sides of a well / pit to make them impermeable and/or stable.
Contact time	1. Period necessary for the reaction of chlorine with organic matter contained in water (at least 30 minutes for chlorine, depending on the pH and temperature of the water to be treated). 2. Time that a high chlorine concentration stays within a well / borehole / reservoir for them to be disinfected (time depending on the method used).
Contamination	Introduction of potentially pathogenic micro-organisms or chemical substances presenting health risks into any environmental medium.
Controlled tipping	Method of disposal of solid wastes by burial in successive layers on a terrain that is exclusively reserved for this purpose. See Sanitary landfill.
Cytotoxic waste	All material that has been in contact with cytotoxic drugs, which are possessing a potential specific destructive action on cells.
Decontamination	Action to reduce contamination risks to harmless levels for people or the environment.
Defecation	Passage of waste matter from the bowels.
Density	Mass of matter within a certain volume.
Detergence	Physical-chemical action of a product combined with a mechanical brushing and rinsing action.
Detergent	Compound used in cleaning products (e.g. washing soap), often found in grey wastewater.
Dewatering pump	Pump that can be completely and partially submerged, as long as its the pumping part is under the water surface. These pumps can normally deal with (rather) dirty water.
Dioxin	Concern about them arises from their (potential) toxicity as contaminants in commercial products or within the exhaust gasses of volume reducers / incinerators. Tests on laboratory animals indicate that it is one of the more toxic anthropogenic products.
Disinfectant	Chemical agent that is able to reduce the viability of micro-organisms on surfaces, liquids (e.g. water) or objects (e.g. medical instruments, waste bins).
Disinfection	Treatment aimed at reducing the number of micro-organisms to safe or relatively safe levels on surfaces, liquids (e.g. water) or objects (e.g. medical instruments, waste bins).
Disposable syringe	An all-plastic syringe designed for single use.
Disposal	Intentional burial, deposit, discharge, dumping, placing or release of any waste material into or on any land sites, air medium, or water bodies as final destination.
Distribution box	Construction for collecting wastewater (e.g. effluent from a septic tank) and distributing it equally among several pipes (e.g. drains in a multiple trench infiltration system).
Domestic waste / Refuse	Putrescible (organic) or non-putrescible solid waste material from household activities. See solid waste.
DPD 1	Chemical used in tablet form with a colorimetric comparator (e.g. pool tester) to measure the Free Residual Chlorine concentration.
DPD 3	Chemical used in tablet form and added to a colorimetric comparator (e.g. pool tester) in which a DPD 1 tablet was already added to measure the Total Residual Chlorine concentration. The difference between the Total Residual Chlorine (TRC) and the Free Residual Chlorine (FRC) gives the Combined Residual Chlorine (CRC) concentration.
Drain	Underground pipe with pierced holes or slots to allow the passage and infiltration of water.
Drainage	Removal of runoff water or wastewater by ditches ("open" system) or pipes ("closed" system).
Drum	Any large (e.g. 200 litres) cylindrical shaped container.
Dumping site	A site used to dispose of (solid) waste without environmental controls. See disposal.
Dwelling	Utilised living space, within or nearby a settlement.
Effective grain size	Range and average dimension of grains of sand or other material used as filtration medium material.

Effluent	Partially or totally treated wastewater coming from a treatment unit and going to secondary treatment or disposal in the environment.
Emergence / Eye	Place where spring water appears at the surface.
Encapsulation	Waste disposal method used to immobilize hazardous waste (e.g. expired or unwanted pharmaceuticals) by containment within a cement, lime and water mixture (3 / 3 / 1 parts by weight) in a sealed drum.
Environmental impact	The positive and negative effects of a certain action on the population, the surrounding mediums (e.g. air, soil, water) and the climate.
Escherichia coliform (E-coli)	A bacteria group often used as the indicator of choice in micro-biological analysis for faecal pollution (of warm blooded animals, humans included).
Evapo-transpiration	Natural process where water is removed / lost into the air by a combination of direct soil evaporation and transpiration by plants. This principle can be used for the disposal of wastewater, particularly in arid areas.
Excreta	Human wastes, particularly faeces and urine.
Faeco-oral transmission	Transmission of pathogens from faecal matter to the digestive system via the mouth (e.g. faecal contamination of water, food, hands).
Ferrocement	Technique of constructing walls by applying layers of cement mortar to a framework of wire / mesh.
Fertilizer	Substance (chemical or organic) used in agriculture to improve soil fertility.
Filtration	Passage of water through a porous medium (filter) that traps solid and sometimes dissolved particles. This principle can happen naturally or be man-made to remove elements that are unwanted and/or hazardous to health (e.g. suspended particles, pathogens).
Final disposal	Disposal that is undertaken without the intention of retrieval in a later stage. See disposal.
Flocculation	Process by which suspended solids in water are aggregated into clusters through biological or chemical action (coagulation), so that they can be separated from water by sedimentation or filtration.
Flock	A cluster of suspended solids formed in the water by biological or chemical action. See flocculation.
Flow rate	The rate at which a fluid is flowing, either naturally or man-made (e.g. pumps). Expressed as volume per time unit (e.g. litres per second, m ³ per hour).
Free Residual Chlorine (FRC)	That fraction of the chlorine that has been added to the water, which is not consumed, nor combined with certain substances in the water, but that remains freely available in excess after a contact time of at least 30 minutes, and has as such still a rapid disinfecting capacity. (desired concentration: 0.2 to 0.5 mg/l if pH < 8; 0.4 to 1.0 mg/l if pH > 8)
Furan	Substance / contaminant found in different concentrations in combustion smoke (e.g. wood), thus also in the exhaust gasses of engines and incinerators, depending on the combustion quality. Furan is carcinogenic to humans and its primary exposure route is inhalation.
Germ	General term that refers to micro-organisms such as bacteria, protozoa, viruses, fungi that are harmful to health.
Gravel	Small (river) stones, used in construction, which can be found naturally or are produced by crushing larger stones.
Grease trap	Special construction for separating grease, fat or oil from grey wastewater, before secondary treatment or its disposal in infiltration facilities (e.g. soak away pit, infiltration trenches) or into the sewer.
Grey water	Domestic wastewater not containing excreta, also called sullage.
Groundwater	Infiltrated water contained in underground porous layers, forming a body of water, which can supply wells and springs.
Hazardous	Intrinsic potential property or ability to cause harm.
Hazardous waste	Waste (often medical) that is considered to be dangerous for health or the environment; includes e.g. expired or unwanted drugs, laboratory reagents, insecticides, X-ray related waste, expired disinfectants.
Health care waste	Waste generated by all kinds of medical activities, including medical waste (sharp, soft, organic and hazardous waste), excreta and wastewater.
Heavy metal	Metallic elements with high atomic weight (e.g. mercury, chromium, cadmium, arsenic, and lead) that can harm living beings at low concentrations and tend to accumulate in the food chain.
Helminths	Scientific name for worms.
Host	A living organism (e.g. human patient, animal) that maintains or harbours an infectious agent (virus, bacteria or parasite). Considered as a part of disease transmission.
Human waste	Faeces and urine (excreta).

Hygiene	Practises related to cleanliness and health as it prevents the dispersion of diseases.
Improved trench latrines	Improved version of normal trench latrines with prefabricated (plastic) slabs and a basic plastic sheeting superstructure for more privacy, still intended for (acute) emergencies.
Incineration	A waste treatment process involving destruction of waste by controlled burning at high temperatures, reducing voluminous waste into ashes.
Incinerator	A furnace for burning (medical) waste under controlled conditions, often utilised in health facilities as a waste treatment tool. In this manual, mainly double combustion chamber furnaces are referred to as incinerators, in contradiction to volume reducers which only have a single combustion chamber.
Inertization	Immobilization of certain powdered / solid hazardous waste (after being crushed) by being embedded within a cement, lime and water mixture (3 / 3 / 1 parts by weight) that solidifies, in order to minimize the risk of toxic substances contained in the waste to migrate to the environment. Used for disposal of pharmaceutical waste.
Infiltration (rate)	The quantity of water that can enter the soil in a specified time interval, normally measured as litre per m ² of infiltration surface a day (l/m ² -day).
Infiltration trench	Structure for disposing of wastewater by underground drainage, using trenches and drains.
Insect	A kind of arthropod. Insects have three distinct body regions (head, thorax and abdomen), three pairs of legs, one pair of antennae, and usually one or two pairs of wings in the adult phase.
Irrigation furrow / Irrigated garden	Vegetable garden watered with clean spilled wastewater recovered from water points (e.g. hand pump, tapstand).
Lancet	Puncturing device used to collect blood drops for medical analysis.
Larva	The intermediary stage between the egg and the pupa, in the development of an arthropod. See arthropod.
Larvicide	A chemical or biological compound which specifically kills insect larva.
Latrine	(External) defecation place for deposition, retention and sometimes decomposition of excreta.
Leachates	Liquid resulting from decomposition of organic matter in a waste bin, dump sites or landfills, sometimes joined with water trickling through. It may result in hazardous substances entering surface or ground water, or the soil.
Lime	Ca(OH) ₂ . Yellowish white stone or powder. Can be found in the environment and has various uses; e.g. construction, water treatment, waste disposal.
Lining	Construction strengthening / sleeving / supporting a mainly underground structure, like for hand dug wells, pit latrines and waste pits.
Luer syringe	Syringe on which a separate needle can be connected with a sliding motion, and disconnected similarly.
Luer-lock syringe	Syringe on which a separate needle can be connected with a screwing motion, and disconnected similarly.
Manure	Animal excreta, normally faecal matter from livestock.
Medical waste	Waste generated by all kinds of medical activities, but excluding excreta and wastewater. In this manual, medical waste is considered under four different categories: sharps, soft (burnable) waste, organic waste and hazardous waste.
Micro-organism	Any micro-biological entity, cellular or non-cellular, capable of replication or of transferring genetic material under certain environmental variables. It includes bacteria, virus, protozoa and microscopic fungi.
Motor pump	Surface pump powered by an electric motor or combustion engine.
NaDCC	Sodium Di-Chloro isoCyanurate. Chlorine-generating product under granular or tablet form, usually containing 55 to 60% active chlorine. By far, the most stable chlorine-generating product.
Needle	Hollowed and pointed steel stem used for puncturing or injecting.
Needle stick injury	Harm caused by unintentional needle puncture. Can cause nosocomial infections, such as hepatitis B, hepatitis C and HIV / AIDS.
Nitrates (NO₃)	A plant nutrient and inorganic fertilizer, nitrates are found in septic systems, animal feed lots, agricultural fertilizers, manure, industrial waste waters, sanitary landfills, and garbage dumps. High levels of nitrates in drinking water should be avoided for newborn babies, small infants and pregnant women, due to the severe health effects that can be caused.
Non-return valve	Valve allowing water to flow in one direction only.
Nosocomial infection	Secondary infection contracted by the patients or the staff while being within a health structure. Often referred to as hospital infection.

Organic matter	Residues or extracts of living organisms.
Organic waste	Biodegradable waste. Waste generated in health care facilities such as amputated limbs, placentas, organs, blood and food residues.
Oxidize	To transform in the oxidized state. Normally signifies the chemical addition of an element (e.g. oxygen) to break down pollutants or organic wastes.
Parasite	An organism which, for all or part of its life, lives in or on the body of another organism (the host) and obtains nourishment from it, without causing the death of the host. Parasites include fungi, arthropods, protozoa, helminths.
Pathogen	Any disease causing organism or substance.
Percolation	The movement of water downward and radial through subsurface soil layers, usually continuing downward to ground water. Slow seepage of water through a filter.
Permeability	The characteristic or the measure of the ease with which water can flow through / infiltrate a solid media / soil.
Pest	An inconvenient insect, rodent, nematode, fungus, weed or other form of terrestrial or aquatic plant or animal life that is injurious to health or the environment.
Pesticide	Substances or mixtures that are intended for preventing, destroying, repelling, or mitigating any pest.
pH	Expression of the degree of acidity or alkalinity of a substance; may range from 0 to 14. The value of 7 is considered as neutral, values below are acidic, values above alkaline (basic).
Pharmaceutical waste	All medicines that cannot be used anymore such as opened but unused drugs, cold chain damaged vaccines, expired and unwanted drugs.
Phenol Red	Chemical compound used to measure the pH by colorimetric comparison (e.g. pool tester), often in tablet form.
Pond	Small body of surface water.
Porosity	The ratio of open space in comparison to the total volume (of soil), which is an indicator of the ability of a medium to pass fluids through it.
Pour flush latrine	Latrine in which the slab has a pan and water trap, and which is flushed manually.
ppm	Parts per million
Precipitation	Water in the form of rain, sleet, hail or snow that falls from the atmosphere onto the land and bodies of water.
Protozoa	Group of unicellular micro-organisms that are larger and more complex than bacteria, certain of which may cause disease in humans (e.g. amoeba).
Pupa	The intermediate stage between the larva and the adult, in the development of an insect.
Radioactive waste	Material that contains or is contaminated with radionuclide at concentrations or activities greater than clearance levels. See radionuclide.
Radionuclide	An atom (nuclide) that exhibits properties of spontaneous disintegration, liberating energy and is accompanied by the emission of different types of (very harmful) radiation.
Rainfall patterns	Historical records of the distribution and quantity of rainfall for a certain area.
Rainwater	Water from atmospheric precipitation which may be collected or form / contribute to a water body.
Rainwater harvesting	Controlled collection and storage of rainwater, to be used for human activities.
Rapid sand filter	Water treatment system at high velocity (4 - 50 m/h) by mechanical filtration (sand bed).
Refuse	Generally domestic solid waste.
Resurgence	Surface water that went underground coming back at the surface, often wrongly interpreted as a spring.
Retention time	1. Time during which wastewater is held in a tank to undergo some form of treatment (e.g.: 1 to 3 days in a septic tank). 2. Time during which combustion gasses stay within the hot environment of an incinerator.
Risk	Probability that a hazard will cause harm, and the severity of that harm.
Rodent	Mammals including rats, mice, squirrels, muskrats, beavers and others. Concern is due to their high infestation rate causing damage to infrastructures, food stocks and potential health risks.
Runoff (water)	That part of the precipitation (e.g. rain, snow, hail, snow melt), or irrigation water that flows naturally on the ground towards surface water bodies (e.g. river, lake).
Safe injection	An injection that does not harm the patient, does not expose the health worker to any risk, and does not result in waste that puts the handlers and/or the community at risk.
Sand	Granular silica compound which is found naturally and is used as building material and filtration medium in water treatment plants.

Sanitary inspection	Field observation, using criteria to evaluate the environmental hygiene status of a settlement (e.g. refugee camp). It should include the inspection of water points (e.g. well, river) and sanitary facilities (e.g. latrines, wastewater disposal), if existing.
Sanitary landfill	Disposal sites for non-hazardous solid wastes spread in layers, compacted to the smallest practical volume, and covered by soil applied at the end of each operating day. In some cases, a specific part of the site can be foreseen to dispose of hazardous waste, or more in general medical waste.
Scalpel	Medical instrument consists of a handle and a sharp disposable blade used in surgical dissection.
Scavengers	Human or animal which depends on refuse (from waste dumps) for survival.
Schmutzdecke	Biological layer (bio film) at the surface of a slow sand filter, playing a purifying role. See slow sand filter.
Sedimentation / Settling	The process of deposition of impurities in water (e.g. suspended solids) to the bottom part of a reservoir, due to gravity.
Segregation	Separation of waste materials (medical waste) into different categories: sharps, soft (burnable), organic and hazardous waste. It is desired to take place at the source where the waste is generated.
Septic tank	Reservoir for collection and partial treatment of wastewater (mainly sewage, and potentially sullage) before further treatment and/or disposal (e.g. into sub-surface drainage, closed sewer).
Sewage	Wastewater containing excreta. Sometimes also called black water.
Sharps	Medical equipment such as needles, scalpel and raiser blades, lancets, and also empty ampoules, vials and broken glass that can cause injuries. Considered after use as a separate category of medical waste.
Sharps container	Recipient used in health facilities for segregating, temporary storage, transportation and eventual disposal of sharp wastes.
Slow sand filter	Water treatment system at low velocity by combination of mechanical filtration (sand bed) and biological purification (Schmutzdecke).
Slurry	A watery mixture of insoluble matter resulting from some pollution control techniques and installations.
Soak away pit	Hole filled with (big) stones, used for infiltration of pre-treated wastewater (from septic tank / grease trap).
Sodium Di-Chloro isoCyanurate	Chlorine-generating product under granular or tablet form, containing 55 to 60% active chlorine, often called NaDCC. By far, the most stable chlorine-generating product.
Sodium hypochlorite	Chlorine-generating product (NaOCl) under liquid form, containing 4 to 15% chlorine, often called bleach. Much less stable than calcium hypochlorite and NaDCC.
Sodium thiosulphate	Crystalline chemical substance used for de-chlorinating drinking water (used during sampling of chlorinated water for micro-biological analysis).
Soil	A complex mixture of inorganic materials (clay, silt, gravel and sand), decaying organic matter, water, air and living organisms, which covers the Earth's surface.
Solid waste	All non-liquid waste.
Spring	Groundwater seeping naturally out of the earth. A spring can be a seasonal or a permanent water source.
Stakeholders	Any organization, governmental entity, or individual that has an interest in or may be affected by a given approach to environmental regulation, pollution prevention, energy conservation, etc.
Standing water / Stagnant water	Water from rain or human activities, which remain static on the ground surface.
Sterile	Any object or media that does not contain germs or any other form of life.
Sterilisation	Elimination of all micro-organisms (viruses, bacteria and microscopic fungi) from water, objects or from a surface.
Stock solution / "Mother solution"	Concentrated solution of 1%, used for treating (chlorination, coagulation - flocculation) a known volume of water.
Storm water	Rainwater running on the ground surface (collected and disposed of separately from wastewater). See runoff water.
Strainer	Sieve to keep back large impurities that are present in the water. It should be installed, often in combination with a non-return valve, at the bottom end of a suction pipe. It is also integrated directly on submersible and dewatering pumps.
Submersible pump	Pump that is completely, as well the pumping part as the electrical motor, under the water surface. Normally designed to pump clean water.
Subsoil	A complete mixture of inorganic materials (clay, silt, gravel, sand) under the ground level and above the bedrock.

Subsurface drainage	Treatment and elimination of wastewater by infiltration into the subsoil.
Subsurface water	All the water which is underground, whether in the saturated or unsaturated zone.
Sullage	Domestic wastewater not containing excreta, also called grey water.
Sulphur dioxide (SO₂)	A pungent colourless gas formed primarily by the combustion of fossil fuels; becomes a pollutant when present in large amounts.
Surface pump	Hand pump or motor pump with the pumping part above the water level and a suction pipe under the water level (suction head limited to 7 m).
Surface water	Water from streams, rivers, lakes, ponds, swamps.
Suspended solids	Small organic and mineral particles that are suspended (hanging around) within a fluid (water).
Thermo-Tolerant Coliforms (TTC)	A bacteria group used as indicator in micro-biological analysis for faecal pollution (of warm blooded animals, humans included). A very large percentage (more than 80%) of the TTC are <i>Escherichia coli</i> forms.
Trench latrines	Long shallow excavations used for defecation during the early stages of certain emergency settlements (e.g. camps).
Turbid water	Water containing fine particles in suspension which give it a cloudy appearance; turbidity is often expressed in (N)TU.
Twin pit latrine	Latrine with two defecation holes and two completely separated pits used alternately.
Vector	An organism, often an arthropod or rodent, that carries disease.
Vector-borne (disease)	Disease which is transmitted by vectors.
Vector control	Measures used to contain the population of pests below certain levels by environmental, chemical and biological methods or techniques.
Ventilated Improved Pit latrine (VIP)	Pit latrine equipped with a ventilation pipe to reduce odours, and with a screen at the top of the pipe to act as a fly trap.
Virus	A sub-microscopic agent that can only multiply inside living cells. Usually very harmful to health.
Volume reducer	A single combustion chamber furnace for burning (medical) waste under controlled conditions, often utilised in small and/or emergency health facilities as a waste treatment tool.
Washing area	Place or structure designed for washing clothes or for personal hygiene (e.g. washing slab, wash tub)
Waste	All items that are considered as not useful anymore, and can therefore be discarded.
Waste area	Solid waste collection place, where refuse is contained and either potentially treated and finally disposed of, or transferred to a treatment and/or disposal place.
Waste management	All the activities, administrative and operational, involved in the potential segregation and conditioning, temporary storage, handling (including transportation), treatment and final disposal of waste.
Waste storage	The placement of waste in a suitable location where isolation, environmental and health protection are provided.
Wastewater	Sewage and sullage. The used water that contains dissolved or suspended matter, and often also pathogens.
Waste zone	Area where the segregated medical waste is collected, potentially treated and finally disposed of.
Watercourse	Stream, river or canal with the direction of water flowing from upstream to downstream.
Water table	Top level of ground water.
Weir	1. A wall or plate placed in an open channel to measure the flow of water. 2. A wall or obstruction used to control flow from settling tanks and clarifiers to ensure a uniform flow rate and avoid short-circuiting.
Well	A drilled, driven or manually dug hole in the ground which enters an underground body of water (aquifer) to allow its abstraction.
Yield	The rate at which a fluid is flowing, either naturally or man-made (e.g. pumps). Expressed as volume per time unit (e.g. litres per second, m ³ per hour).

Conversion tables

Distances

1 km	=	0.6214 miles	
1 m	=	1.0936 yards (yd)	
1 cm	=	0.3937 inches (in)	
1 mile	=	1.6093 km	
1 yard	=	0.9144 m	
1 foot	=	0.3048 m	
	=	30.48 cm	
1 inch	=	2.54 cm	

Surface

1 km ²	=	100 ha	= 0.386 miles ²
1 ha	=	10000 m ²	= 2.471 acres
1 m ²	=	10000 cm ²	= 1.196 yd ²
1 mile ²	=	2.59 km ²	= 240 acres
		259 ha	
1 acre	=	0.405 ha	= 4840 yd ²
1 yd ²	=	0.836 m ²	= 9 ft ²
1 ft ²	=	0.093 m ²	= 144 inch ²
	=	930 cm ²	
1 inch ²	=	6.45 cm ²	

Volume

1 m ³	=	1.308 yd ³	= 1000 litres
	=	35.32 ft ³	
1 cm ³	=	0.061 in ³	= 1 ml
1 yard ³	=	27 ft ³	= 765 litre
1 foot ³	=	1728 in ³	= 28.32 litre
1 inch ³	=	16.39 cm ³	= 16.39 ml

Capacity

1 litre	=	0.22 UK Gal	
	=	1.76 UK Pints	
	=	0.26 US Gal	
	=	2.11 US Pints	
1 ml	=	0.0675 fluid	
1 UK Gal	=	4.546 litres	
	=	1.20 US Gal	
1 US Gal	=	3.791 litres	
	=	0.83 UK Gal	

Weight

1 tonne	=	0.984 long (UK) tons	
	=	1.102 short(US) tons	
	=	2204 pounds (lb)	
1 kg	=	2.2046 lb	
	=	35.27 oz	
1 g	=	0.03 oz	
1 UK ton	=	1016 kg	= 2240 lb
1 US ton	=	907.01 kg	
1UK ton	=	1.1 US ton	
1 lb	=	0.4536 kg	= 16 oz
	=	453.6 g	
1 oz	=	28.35 g	

Temperatures

$^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32)$
$^{\circ}\text{F} = 9/5 ^{\circ}\text{C} + 32$
Examples:
$0 ^{\circ}\text{C} = 32 ^{\circ}\text{F}$
$100 ^{\circ}\text{C} = 212 ^{\circ}\text{F}$
$0 ^{\circ}\text{F} = - 17.78 ^{\circ}\text{C}$
$100 ^{\circ}\text{F} = 37.78^{\circ}\text{C}$

Material and work estimations

(adapted from: *A Handbook of Gravity-Flow Water Systems*)

EXCAVATIONS	Per m³
Ordinary soil	0.55 man-day (m-d)
Gravelly soil	0.77 m-d
Boulder mix	1.10 m-d
Medium rock cutting	1.60 m-d
Hard rock cutting	2.50 m-d

BRICK MASSONRY (1-4 mortar)	Per m³
Bricks	75 %
Cement	0.063 m ³
Sand	0.25 m ³
Mason labour	1.4 m-d
Unskilled labour	2.8 m-d

WOOD WORKING	Per m³ of finished wood
Skilled labour	18 m-d
Unskilled labour	18 m-d

RUBBLE-STONE MASONRY (1-4 mortar)	Per m³
Cement	0.088 m ³
Sand	0.35 m ³
Mason labour	1.4 m-d
Unskilled labour	3.2 m-d

STONE AGGREGATE PRODUCTION	Per m³ of crushed rock
Unskilled labour	14 m-d

DRESSED-STONE MASSONRY (1-4 mortar)	Per m³
Cement	0.075 m ³
Sand	0.30 m ³
Mason labour	2.8 m-d
Unskilled labour	5.0 m-d

CONCRETE	concrete	Lean concrete:
Per m³:	1-2-4 mix	1-4-8 mix
Cement	0.25 m ³	0.125 m ³
Sand	0.50 m ³	0.50 m ³
Aggregate	1.00 m ³	1.00 m ³
Mason labour	1.1 m-d	1.1 m-d
Unskilled labour	4.0 m-d	4.0 m-d

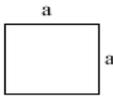
PLASTER* per m³	1-3 mix
Cement	0.003 m ³
Sand	0.01 m ³
Mason labour	0.14 m-d
Unskilled labour	0.22 m-d

* Each coat of plaster 1 cm thick

SPECIFIC WEIGHTS	kg / m³
Portland cement:	1440
Brick masonry:	2120
Stone masonry:	2450
Concrete:	2409
Seasoned wood:	650
Water:	1000
Dry-stone masonry:	2000

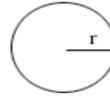
Perimeter

Square:



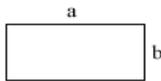
Perimeter = $4a$

Circle



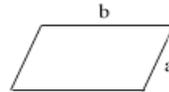
Perimeter = $2 \times \pi \times r$

Rectangle:



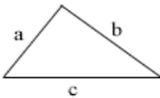
Perimeter = $2a + 2b$

Parallelogram:



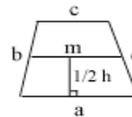
Perimeter = $2a + 2b$

Triangle:



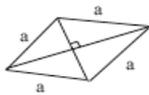
Perimeter = $a + b + c$

Trapezoid:



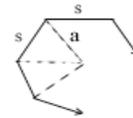
Perimeter = $a + b + c + d = 2m + c + d$

Rhombus:



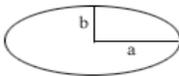
Perimeter = $4a$

Regular N-gon:



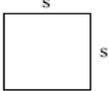
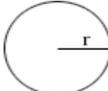
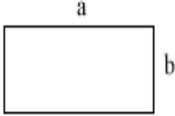
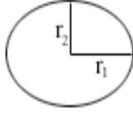
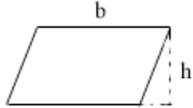
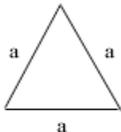
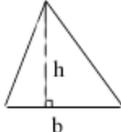
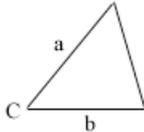
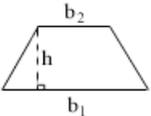
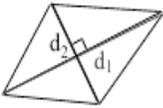
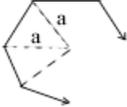
Perimeter = ns , $n = \#$ of sides

Ellipse:



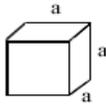
Perimeter = $2 \pi \sqrt{\frac{a^2 + b^2}{2}}$

Area

<p style="text-align: center;">Square:</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Area = s^2</p>	<p style="text-align: center;">Circle:</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Area = $\pi \times r^2$</p>
<p style="text-align: center;">Rectangle:</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Area = $a \times b$</p>	<p style="text-align: center;">Ellipse:</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Area = $\pi \times r_1 \times r_2$</p>
<p style="text-align: center;">Parallelogram:</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Area = $b \times h$</p>	<p style="text-align: center;">Equilateral Triangle:</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Area = $\frac{\sqrt{3}}{4} (a^2)$</p>
<p style="text-align: center;">Triangle:</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Area = $\frac{1}{2}(b \times h)$</p>	<p style="text-align: center;">Triangle given SAS (two sides and the opposite angle):</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Area = $\frac{1}{2} \times a \times b \times \sin C$</p>
<p style="text-align: center;">Trapezoid:</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Area = $\frac{1}{2}h(b_1 + b_2)$</p>	<p style="text-align: center;">Rhombus:</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Area = $\frac{1}{2} \times d_1 \times d_2$</p>
<p style="text-align: center;">Regular Polygon:</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Area = $\frac{1}{2} n a^2 \sin \left(\frac{360^\circ}{n} \right)$</p> <p style="text-align: center;">n = # of sides</p>	

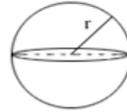
Volume

Cube:



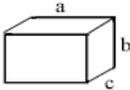
$$\text{Volume} = a^3$$

Sphere:



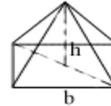
$$\text{Volume} = \frac{4}{3} \times \pi \times r^3$$

Rectangular Prism:



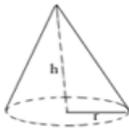
$$\text{Volume} = a \times b \times c$$

Pyramid:



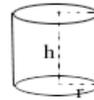
$$\text{Volume} = \frac{1}{3} \times b \times h$$

Cone:



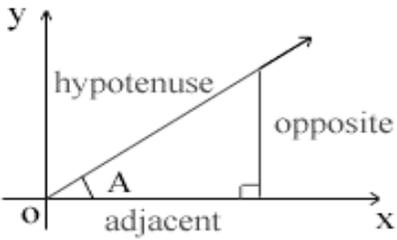
$$\text{Volume} = \frac{1}{3} \times \pi \times r^2 \times h$$

Cylinder:



$$\text{Volume} = \pi \times r^2 \times h$$

Trigonometric Formula

$\sin A = \frac{\text{opposite}}{\text{hypotenuse}}$	
$\cos A = \frac{\text{adjacent}}{\text{hypotenuse}}$	
$\tan A = \frac{\text{opposite}}{\text{adjacent}}$	
$\cot A = \frac{\text{adjacent}}{\text{opposite}}$	
$\sec A = \frac{\text{hypotenuse}}{\text{adjacent}}$	
$\csc A = \frac{\text{hypotenuse}}{\text{opposite}}$	

Given Triangle abc, with angles A,B,C; a is opposite to A, b opposite B, c opposite C:

$$a/\sin(A) = b/\sin(B) = c/\sin(C) \quad | \quad \text{(Law of Sines)}$$

$$c^2 = a^2 + b^2 - 2ab \cos(C)$$

$$b^2 = a^2 + c^2 - 2ac \cos(B)$$

$$a^2 = b^2 + c^2 - 2bc \cos(A)$$

| (Law of Cosines)

$$(a - b)/(a + b) = \tan [(A-B)/2] / \tan [(A+B)/2] \quad | \quad \text{(Law of Tangents)}$$