SANITATION SAFETY PLANNING

MANUAL FOR SAFE USE AND DISPOSAL OF WASTEWATER, GREYWATER AND EXCRETA

World Health Organization

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FOREWORD

“Poverty can never be eradicated, or even greatly reduced, as long as so many millions of people cannot access safe water and so many billions are living in environments contaminated by faeces. Sanitation, together with hygiene, must be given a much higher place in any agenda for future development and must be urgently and frankly addressed.”

Margaret Chan, WHO Director General

At any given time, nearly half the population of the developing world will be affected by an illness or disease directly linked to unsafe or too little water, poor or no sanitation, or poor management of water resources.

Increasing access to basic sanitation at the household level remains a critical public health intervention for preventing sanitation related disease especially for diarrhoea, intestinal worms, schistosomiasis and trachoma which affect millions of people.

Yet, providing safe affordable sanitation is becoming more complex. Preventing exposure to human waste, especially in dense urban settings, requires safe management of the entire sanitation chain involving multiple actors and exposed groups in the collection, transport, treatment, disposal and use of sanitation waste. Although evidence is limited, global burden of disease estimates for diarrhoea show that this higher level of service is effective and can achieve large health gains over and above what can be achieved with basic sanitation alone.

As pressures of urbanization, demand for food and water scarcity increase, reuse of sanitation waste is becoming more attractive and viable. Many authorities and enterprises are working on sanitation service chain models that make beneficial use of nutrients, water and energy and offset the cost of service provision. These models can offer health benefits by removing excreta from the environment and increasing food production.

However, health concerns are a major challenge for such approaches. Proponents operate in fragmented and unsupportive policy environments that are often weakly linked to health. They also need to overcome negative public perceptions about the risks associated with use and disposal of human waste.

Sanitation Safety Planning is a tool to help sanitation system operators maximise health benefits and minimise health risk of their system. It guides operators to prioritize and target risk management efforts to where it will have the most impact and to improve over time. The outputs can be used to provide assurance to the public and authorities of the system performance based on sound risk based management.

Perhaps most importantly, Sanitation Safety Planning can be used to coordinate efforts of the many stakeholder along the sanitation chain – including departments of health, utilities, private sector, environment and agriculture authorities – to maximise the health benefits of sanitation and stimulate policy dialogue and change.

WHO will continue to promote the principles of risk assessment and management for sanitation systems and the scaling of Sanitation Safety Planning.

Maria Neira
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The Sanitation Safety Planning approach was tested with national authorities in Hanoi, Viet Nam; Karnataka, India; Lima, Peru; Kampala, Uganda; Benavente, Portugal; and Manila, Philippines under the guidance of a strategic advisory group and with review by experts and practitioners. Contributors are listed below:

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CONTENT

GLOSSARY

This glossary gives plain language explanations of terms frequently used in the *WHO Guidelines for Safe Use of Wastewater, Excreta and Greywater* (2006 WHO Guidelines), and in this SSP manual. It does not aim to provide precise definitions of technical or scientific terms. For a more extensive glossary, refer to 2006 WHO Guidelines (Volume 1, Annex 1; Volume 2, Annex 4; Volume 3, Annex 4 and Volume 4, Annex 1).

Term	Plain language explanation
Aquaculture	Raising plants or animals in water (water farming).
Control measure	Any action and activity (or barrier) that can be used to prevent or eliminate a sanitation-related hazard, or reduce it to an acceptable level.
DALY	Disability-adjusted life years (DALYs). Population metric of life years lost to disease due to both morbidity and mortality.
Disease vector	Here defined as an insect that carries disease from one animal or human to another (e.g. mosquitoes).
Escherichia coli (E. coli)	A bacterium found in the gut. It is used as an indicator of faecal contamination of water.
Excreta	Faeces and urine (see also faecal sludge, septage and nightsoil).
Exposure	Contact of a chemical, physical or biological agent with the outer boundary of an organism (e.g. through inhalation, ingestion or dermal [skin] contact).
Exposure route	The pathway or route by which a person is exposed to a hazard.
Faecal sludge	Sludges of variable consistency collected from on-site sanitation systems, such as latrines, non-sewered public toilets, septic tanks and aqua privies. Septage, the faecal sludge collected from septic tanks, is included in this term (see also excreta and nightsoil).
Greywater	Water from the kitchen, bath and/or laundry which, generally, does not contain significant concentrations of excreta.
Hazard	A biological, chemical or physical constituent that can cause harm to human health.
Hazardous event	An event in which people are exposed to a hazard in the sanitation system. It may be an incident or situation that: • introduces or releases the hazard to the environment in which humans are living or working, • amplifies the concentration of a hazard, or • fails to remove a hazard from the human environment.
Health-based target	A defined level of health protection for a given exposure. This can be based on a measure of disease, or the absence of a specific disease related to that exposure. In the 2006 WHO Guidelines, the health-based target recommended is 10^{-6} DALY per person per year.
Health impact assessment	The estimation of the effects of any specific action (plans, policies or programmes) in any given environment on the health of a defined population.

Helminth	Helminths are a broad range of organisms that include intestinal parasitic worms: trematodes (flatworms, also commonly known as flukes, e.g. *Schistosoma*), nematodes (roundworms, e.g. *Ascaris, Trichuris* and the human hookworms) or cestodes (tapeworms, e.g. *Taenia solium*, the "pork tapeworm").
Highly mechanized farming	Farming practices where farm workers typically plough, sow and harvest using tractors and associated equipment and could be expected to wear gloves when working in irrigated fields. This is representative of exposure conditions in industrialized countries.
High-growing crops	Crops that grow above the ground and do not normally touch the ground (e.g. most fruit crops).
Infection	The entry and development or multiplication of an infectious agent in a host. Infection may or may not lead to disease symptoms (e.g. diarrhoea). Infection can be measured by detecting infectious agents in excreta or colonized areas or through measurement of a host immune response (i.e. the presence of antibodies against the infectious agent).
Intermediate host	The host occupied by juvenile stages of a parasite prior to the definitive host and in which asexual reproduction often occurs. For example, specific species of snails are the intermediate host of *Schistosoma*, a parasitic flatworm causing schistosomiasis.
Labour intensive farming	Farming practices, typical in developing countries, in which the practice puts people in close contact with soil, water and produce.
Lead organization	The organization or agency that takes the lead in a SSP process.
Leaf crops	Crops in which the leaf portions are harvested and either eaten raw or cooked (e.g. lettuce, celery, spinach, salad greens).
Localized irrigation	Irrigation application technologies that apply the water directly to the crop, through either drip irrigation or bubbler irrigation. Generally, localized irrigation systems use less water, resulting in reduced crop contamination and a reduction in human contact with the irrigation water.
Log reduction	Organism reduction efficiencies: 1 log unit = 90%; 2 log units = 99%; 3 log units = 99.9%; and so on.
Low-growing crops	Crops that grow below, or just above, but in partial contact with the soil (e.g. carrots, lettuce, tomatoes or peppers, depending on growing conditions).
Nightsoil	Untreated excreta transported without water (e.g. via containers or buckets).
Operational monitoring	The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a control measure is operating within design specifications (e.g. for wastewater treatment turbidity). Emphasis is given to monitoring parameters that can be measured quickly and easily and that can indicate if a process is functioning properly. Operational monitoring data should help managers to make corrections that can prevent hazard break-through.
Pathogens	Disease-causing organisms (e.g. bacteria, helminths, protozoa or viruses).
Quantitative microbial risk assessment (QMRA)	Method for assessing risk from specific hazards through different exposure pathways. QMRA has four components: hazard identification, exposure assessment, dose-response assessment and risk characterization.
Restricted irrigation	Use of wastewater to grow crops that are not eaten raw by humans (i.e. they are cooked before eating, e.g. potatoes).
Risk	The likelihood and consequences that something with a negative impact will occur.

Root crops	Crops in which the root portion of the crop is edible (e.g. carrots, potatoes, onions, beetroot).
Sanitary inspection	A sanitary inspection is an on-site inspection and evaluation, by qualified individuals, of all conditions, devices, and practices in the sanitation system that pose an actual or potential danger to the health and well-being of the various exposure groups. It is a fact-finding activity that should identify system deficiencies—not only potential sources of hazardous events, but also inadequacies and lack of integrity in the system or that could lead to hazardous events.
Sanitary surveillance	A surveillance programme, often incorporating sanitary inspections, which gives a continuous and vigilant public health assessment of the safety and acceptability of the sanitation system.
Sanitation step	Sanitation steps are elements or building blocks of the SSP system to help analyse the sanitation system. Typically, elements may consist of: generation of wastes, collection/ transportation (or conveyance), treatment, use or disposal.
Sanitation system	The combined sanitation chain from waste generation to final use and disposal.
Septage	Faecal sludge collected from septic tanks.
Severity	The degree of impact on health if the hazardous event occurred.
SSP system assessment	Assessment of the hazards and risks in the SSP system.
SSP system boundary	A boundary within which the SSP is conducted.
Tolerable health risk	Defined level of health risk from a specific exposure or disease that is tolerated by society, it is used to set health-based targets.
Unrestricted irrigation	The use of treated wastewater to grow crops that are normally eaten raw.
Validation	(1) Proving that the system and its individual components are capable of meeting the specified targets (i.e. microbial reduction targets). Validation should be part of the documentation when a new system is developed or new processes are added. (2) In respect of validation of the system description (explained in Module 2 of this manual): validation provides evidence of the assumed system characteristics and performance (e.g. claimed extent of contamination reduction).
Vector-borne disease	Diseases (e.g. malaria, leishmaniasis) that can be transmitted from human to human via insect vectors (e.g. mosquitoes, flies).
Verification monitoring	The application of methods, procedures, tests and other evaluations, in addition to those used in operational monitoring, to determine compliance with the system design parameters and/or whether the system meets specified requirements (e.g. microbial water quality testing for *E. coli* or helminth eggs, microbial or chemical analysis of irrigated crops).
Waste stabilization ponds	Shallow basins that use natural factors such as sunlight, temperature, sedimentation, biodegradation, etc., to treat wastewater or faecal sludges. Waste stabilization pond treatment systems usually consist of anaerobic, facultative and maturation ponds linked in series.

ABBREVIATIONS

BOD	biochemical oxygen demand
C	consumers exposure group
COD	chemical oxygen demand
DALYs	Disability-adjusted life years
F	farmers exposure group
HACCP	hazard analysis and critical control point
HIA	health impact assessment
L	local community exposure group
NGO	non-governmental organization
QMRA	quantitative microbial risk assessment
SOP	standard operating procedure
SS	suspended solids
SSP	sanitation safety planning
STPH	Swiss Tropical and Public Health Institute
W	workers exposure group
WHO	World Health Organization
WSP	water safety plans
WWTP	wastewater treatment plant

INTRODUCING SANITATION SAFETY PLANNING (SSP)

Why Sanitation Safety Planning

The underlying purpose of sanitation interventions is to protect public health. Management and investments in improvements on sanitation systems should be made based on adequate understanding of the actual health risks posed by the systems and how these risks might best be controlled.

Sanitation Safety Planning (SSP) is a risk based management tool for sanitation systems. This manual focuses on safe use of human waste. It assists users to:

- systematically identify and manage health risk along the sanitation chain;
- guide investment based on actual risks, to promote health benefits and minimize adverse health impacts;
- provide assurance to authorities and the public on the safety of sanitation-related products and services.

SSP provides a structure to bring together actors from different sectors to identify health risks in the sanitation system and agree on improvements and regular monitoring. The approach ensures that control measures target the greatest health risks and emphasises incremental improvement over time. It is applicable in high and low resource settings. It can be used both at the planning stage for new schemes, and to improve the performance of existing systems.

SSP underscores the leadership role of the health sector in the use of wastewater, excreta and greywater, and helps to bring a human health perspective to traditional non-health sectors like sanitation engineering and the agricultural sector.

Target audiences, uses and approach

This SSP manual provides practical step-by-step guidance to assist in the implementation of the 2006 WHO Guidelines for Safe Use of Wastewater, Excreta and Greywater. However, the approach and tools in the manual can be applied to all sanitary systems to ensure the system is managed to meet health objectives.

The SSP manual is targeted at a variety of users at different levels:

- local authorities (e.g. as a tool for planning investment in sanitation especially in low resource settings);
- wastewater utility managers (e.g. to assist in managing effluent quality and safeguarding public and occupational health from source to end use or disposal);
- sanitation enterprises and farmers (e.g. to complement quality assurance procedures for safety of end products, workers, local communities, and consumers or users of the product);

WHO Guidelines for Safe Use of Wastewater, Excreta and Greywater

The 2006 WHO Guidelines for Safe Use of Wastewater, Excreta and Greywater provide a comprehensive framework for managing health risks associated with the use of human wastes in agriculture and aquaculture. The 2006 Guidelines superseded the 1973 and 1989 guidelines and, for the first time, removed effluent water quality thresholds. Instead, they offer flexibility to select a range of treatment and non-treatment options along the sanitation chain to achieve health protection targets. This change recognized that high levels of treatment are not always feasible or the most cost effective and that use of untreated or partially treated wastewater, excreta and greywater is common in many settings.

There is no reliable estimate of the extent of formal and informal use of wastewater, excreta and greywater. However, it is clear the practice is significant and increasing globally.

Use of wastewater is becoming increasingly attractive to policy makers and water users in the face of increasing water scarcity and competing demands for water. Peri-urban agricultural and aquaculture using wastewater also has many market advantages. In addition to being a reliable year-round water supply, wastewater also contains valuable nutrients that can increase crops yields and save on artificial fertilizers and alternative water sources.

However, expanding formal reuse is typically complicated by weak coordination, complexity in the inter-operability of policies and regulations for reuse, and difficulties in identifying and managing the real and perceived health risks associated with reuse.

The 2006 WHO Guidelines are designed to assist in the development of national and international approaches and to provide a framework for national and local decision making to identify and manage health risk associated with use of wastewater, excreta and greywater in agriculture and aquaculture. Crucially, the 2006 Guidelines recognize that changes in policy and investment in improvements, be they capital works operational or behavioural measures, involve multiple actors and take time.

This SSP Manual assists users to implement the guidelines by presenting the recommended risk based approaches in stepwise process. The concepts of coordination and incremental improvement over time are central to the SSP approach.

- community based organizations, farmers associations and NGOs (e.g. to support community based water and sanitation programs in safe use of human wastes).

In addition to its site specific use related to a particular SSP process, SSP is also useful for those working at a national level, including:

- health authorities and regulators (e.g. as a tool to introduce risk based approaches in the sanitation sector, and verify their effectiveness);
- those guiding the development of policies and programmes to improve the sanitation management.

SSP is not intended to be used for planning and designing new large sanitation schemes. In these cases, the planning may be complemented by specialized studies such as health impact assessments (HIA). Once the scheme has been developed, SSP can be used as an ongoing management tool.

This manual presents the SSP process in six modules (Figure 1). The following chapters guide the user through these six modules, and each includes additional guidance notes, SSP tools and examples as appropriate.

FIGURE 1. SSP MODULES

An enabling policy environment for SSP

Ultimately, a country or region should establish policy frameworks and capacities for sustaining implementation and quality SSP. This enabling environment should include provisions for three separate functions related to SSP:

- risk assessment and management approaches in the national policy framework;
- SSP implementation by operators; and
- SSP surveillance overseen by an independent authority.

The development of this enabling environment will have many similarities to the development phase of a Water Safety Plan (WSP) framework in many countries. However, given the inter-sectoral nature of sanitation and resource recovery and reuse operations, the process may require prolonged policy discussion to achieve sector-wide endorsement and inter-sectoral cooperation.

The Steering Committee outlined in Module 1.1 should have the overall coordinating authority for SSP and be the forum for policy dialogue and amendment as needed to create an enabling environment for safe resource recovery, reuse and SSP.

Given the complex nature of policy change, SSP may be undertaken in advance of a specific policy framework, and its results used to inform the policy dialogue. SSP assessments such as routine surveillance or audits should ensure the sustained high quality management of sanitation systems, and provide feedback on performance.

Volume 1 of the 2006 WHO Guidelines provides more guidance on the principles of this enabling environment and policy setting.

Applying the 2006 Guidelines, Jordan

Jordan is a pioneer country in practicing planned agricultural wastewater use. Since 1977, Jordanian government officially promotes agricultural wastewater use and considers treated wastewater a valuable resource for agricultural sector. Approximately, 93% of treated wastewater is used for irrigation, of which 24% is directly used to irrigate 3500 ha.

Direct use is regulated by contracts between farmers and the Ministry of Water and Irrigation. The contracts limit farmers to cultivating fodder crops and trees even through regulations also allow irrigation of vegetables eaten cooked, cereals and industrial crops. The additional restriction came primarily from unverified health concerns and limited monitoring capacities.

In 2014, the Jordanian authorities issued guidelines for irrigation water quality. The guidelines adopted the more flexible the health based target approach described in the WHO 2006 Guidelines. An implementation framework is being developed to tackle operational, legislative and institutional aspects with a focus on applying risk assessment and management tools and improving monitoring.

Comparison of Sanitation Safety Planning with Water Safety Planning

Many readers will be familiar with Water Safety Plans (WSPs). Like WSPs, SSP is based on the Stockholm framework for preventive risk assessment and management and uses the methods and procedures of hazard analysis and critical control point (HACCP).

WSPs provide a systematic approach towards assessing, managing and monitoring risks from catchments to drinking-water consumers. Similarly SSP applies the approach from sanitation waste generation (e.g. the toilet) to the waste's final use and/or disposal. For example, in the case of reuse/recycled waste streams in agriculture which produce a food product, SSP goes from "toilet to farm to table", or for waste streams which are released to the environment, from "toilet to environment".

There are, however, critical differences in the two approaches. SSP typically operates in a less defined regulator environment, has multiple objectives, has more stakeholders and addresses risks to multiple exposure groups.

	Sanitation Safety Planning	Water Safety Planning
Similarities	Derived from WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater	Derived from the WHO Guidelines for Drinking-water Quality
	Uses risk management, HACCP, Stockholm Framework (see Note)	Uses risk management, HACCP, Stockholm Framework
	Core components: (1) system assessment; (2) monitoring; (3) management	Core components: (1) system assessment; (2) monitoring; (3) management
	Follows the sanitation chain	Follows the drinking-water supply chain
Differences	Considers multiple exposure groups for microbiological, physical and chemical hazards	Considers single exposure group (drinking-water consumer) for microbiological, physical, chemical and radiation hazards
	Expands from waste generation to its uses and discharges into the environment	Contracts from catchments and converges to the drinking-water delivery point
	Usually no clear regulatory framework – roles and responsibilities are shared over different sectors and levels	Usually operates in a clear regulatory framework
	Objectives – reduce negative health impacts of use of wastewater, excreta or greywater while maximizing the benefits of their use	Objectives –- to consistently ensure the safety and acceptability of a drinking-water supply and to reduce the risk of drinking-water contamination
	Implementing agency – varies depending on objectives, skills and resources	Implementing agency – water utility or a community association for small supplies

Note: The Stockholm Framework creates a harmonized framework for the development of guidelines and standards, in terms of water-related microbiological hazards. It provides the conceptual framework of the 2006 WHO Guidelines. In its simplest form, its key elements are: assessment of public health and of risks; health targets; risk management based on informed environmental exposure and acceptable risk (see 2006 WHO Guidelines Vol. 1, 36 for more details).

MODULE 1

PREPARE FOR SANITATION SAFETY PLANNING

MODULE 1
PREPARE FOR SSP

MODULES

1.1 Establish priority areas or activities
1.2 Set objectives
1.3 Define the system boundary and lead organization
1.4 Assemble the team

OUTPUTS

- **Agreed priority areas, purpose, scope, boundaries and leadership for SSP**
- **A multidisciplinary team representing the sanitation chain for development and implementation of SSP**

Overview

Preparing for the SSP process requires clarity on the priority area, the specific public health objectives of the SSP and the components in the sanitation chain that need to be included to meet the objectives. Additionally a lead organization and team need to be identified. These should represent the various steps of the sanitation system.

Module 1.1 establishes the priority sanitation challenges for in-depth SSP, to ensure the SSP addresses the areas or activities that pose the greatest health risks.

Module 1.2 focuses the SSP outputs by ensuring they respond to the agreed public health objectives for the system.

Module 1.3 helps to drive and sustain the SSP process and to ensure that the scope is understood by all stakeholders and is manageable.

Modules 1.1, 1.2 and 1.3 are interrelated, and an iterative process may need to be followed for completing the actions until they are fully harmonized.

Module 1.4 ensures broad stakeholder commitment to design and implement the entire SSP process. In sanitation systems this is particularly important, as responsibility along the sanitation chain is seldom the purview of one organization.

Module 1 should be developed to suit the local circumstances and context.

1

1.1 Establish priority areas or activities

Entities interested in a sanitation system that is already at a manageable scale or only entails a single sanitation activity may not need to conduct Module 1.1, as their priority area or activity is already defined. It should, however, in its SSP consider the full sanitation chain from waste generation to reuse or disposal for its particular area or activity.

Module 1.1 is relevant for entities that have interest or responsibilities for a broad range of sanitation activities (e.g. municipal authorities, wastewater utility companies, health authorities). This action helps to identify the particular foci of the SSP process. This involves establishing a Steering Committee and identifying and agreeing on a SSP priority area(s) within a larger geographical area (e.g. a city or district). Alternatively a decision can be made to focus a particular sanitation activity (e.g. faecal sludge management). This should ensure the SSP addresses the areas or issues that pose the greatest health risks, while recognizing that health risks may vary over time, seasonally or as a result of epidemics.

The Steering Committee should be a representative body with combined oversight of sanitation/reuse activities in the area. Its outputs would include:

- leadership and oversight of the entire process;
- agreed priority areas for SSP;
- engagement with, and commitment of, senior management of the lead agency, and secured financial and resource commitment;
- policy dialogue and amendment as needed to create an enabling environment for safe resource recovery and reuse.

Considerations for selecting priority areas or activities include:

a) Coverage and performance of sanitation systems:
- all waste discharge, treatment, collection, processing, disposal and reuse points with particular emphasis on waste streams that receive inadequate or unknown treatment and high risk wastes (e.g. hospitals and industrial discharges);
- type and condition of toilets including location and frequency of open defecation;
- faecal sludge management, location and discharge, dumping or sludge use sites;
- untreated or partially treated wastewater discharges to stormwater drains and open channels, and their downstream impacts;
- activities in which human waste is mixed, processed or disposed with animal or solid wastes.

b) Exacerbating factors:
- areas with high reported or suspected sanitation-related disease (e.g. soil-transmitted helminthiasis, schistosomiasis and intestinal protozoa infections);
- areas of high population density;
- vulnerable populations (e.g., migrant camps/informal settlements, waste pickers, people living near highly polluted surface water bodies);
- flood prone areas;
- water supply catchments and intakes affected by wastewater, excreta or greywater;
- areas with no or intermittent water supply service which therefore require self-supply from potentially unsafe water sources;

- areas with high formal or informal wastewater use activities (e.g. agriculture and aquaculture);
- outfall areas where shellfish harvesting is practiced;
- popular areas for recreation, especially swimming, which have some waste inputs.

1.2 Set objectives

Setting specific SSP objectives helps to define the purpose of the SSP process. While the overall objective should always relate to improved public health outcomes, other objectives may be related to wastewater management and its use, or have more broad regional or national significance (e.g. promotion of safe biosolids use). Example 1.1 shows some typical SSP objectives.

1.3 Define the system boundary and lead organization

The SSP boundary should reflect the specific SSP objectives defined in Module 1.2. Clear boundaries need to be defined and a lead institution identified.

The SSP boundaries may need to be defined to suit:
- the scope of operations of a sanitation business;
- administrative boundaries;
- sanitation catchment area;
- areas where waste products are used;
- a specific product;
- protection of specific exposure group.

In practice, it is common that the boundaries do not fit neatly into any one of these classifications. Sub-systems within the overall system boundary can be defined.

The lead organization does not need to be responsible for all sanitation steps within the boundary. Unlike WSPs, where institutional ownership rests with the water utility, the lead institution for SSP will depend on the boundary and purpose of the SSP.

See Examples 1.2 to 1.6 and Worked example: SSP in Newtown.

1.4 Assemble the team

Conduct a stakeholder analysis and select expertise for the team

Often the SSP process is initiated by one or several interested individuals or an organization. They, however, are unlikely to have the necessary skills to identify all the problems, represent the whole system, and drive improvements in all areas of the sanitation system. In order to make the SSP successful, the initiator will need the support of:
- managers within the relevant organizations to allocate staff time and resources to the SSP effort;
- a team representing a range of technical skills along the sanitation chain and also stakeholders.

Multiple stakeholders on the SSP team are preferable. SSP team members should be identified through a stakeholder analysis (see Tool 1.1 and Example 1.7) to ensure all that sanitation steps outside the responsibilities of the lead institution are represented. The team may also include representatives of key exposure groups where appropriate (also see Module 2).

The SSP team should include people with a mix of health and technical skills so that members are collectively able to define the system, identify hazards and hazardous events, and understand how the risks can be controlled (e.g. it should include relevant agricultural and/or aquacultural expertise). Balance should be sought in terms of technical skills, stakeholder perspectives including gender, and representation of vulnerable or socially excluded sub-groups.

While some stakeholders may be important, their inclusion in the SSP team may not be warranted due to availability, skill level or the practicality of maintaining a manageable number of people in the team. Engagement with these stakeholders should be addressed under the supporting programmes discussed in Module 6.

Depending on the scale of the system it may be appropriate to include independent members (e.g. universities and research institutes). Alternatively, they may be included separately in the periodic health surveillance by health authorities and external assessment (see Module 5.3) or in the SSP Steering Committee (see Module 1.1).

See Guidance Note 1.1 and Examples 1.8 to 1.11.

Appoint a team leader

A team leader should be appointed to drive and focus SSP. This person should have the authority, organizational and interpersonal skills to ensure the project can be implemented.

In situations where required skills are unavailable locally the team leader should explore opportunities for external support such as partnering arrangements with other organizations, national or international assistance programmes and training resources, and consultants.

Define and record roles of the individuals on the team

It is important to divide responsibilities among the team members at the start of the process and clearly define and record their roles. For large teams it is often helpful to put together a table outlining SSP activities and who will be responsible for carrying them out (See Tool 1.2).

Management and financial considerations

The SSP effort will require an in kind commitment of time and some direct costs during the preparation phase (e.g. sampling and testing, data collection and field investigations). During Module 1, provisional estimates can be made by considering the likely data requirements of Module 2 and likely additional testing required from the application of Module 5. Management support will be needed for the SSP process to allocate staff time and any start-up funding needed if required.

GUIDANCE NOTE 1.1

Checklist of issues to consider when identifying the SSP team and allocating responsibilities

- Are organizations (or stakeholders) for all steps of the sanitation chain represented?
- Are day-to-day technical operational skills included?
- Does one or more member have an understanding of management systems and emergency procedures?
- Do members have the authority to implement recommendations stemming from the SSP?
- How will the work be organized? Will the activities be regular or periodic?
- Can the team activities be done as part of regular activities?
- How will specific stakeholders not represented on the team be engaged?
- How will documentation be organized?
- What external technical support can be brought in to support the team?

TOOL 1.1

Stakeholder analysis

SANITATION STEP	STAKEHOLDER	ROLE OF STAKEHOLDER	MOTIVATING FACTORS	CONSTRAINING FACTORS
See Note 1	See Note 2	See note 2: Direct control, influence, affected by, or interest in	List factors which may motivate the stakeholder in adoption of a safe system	List factors which may demotivate the stakeholder in adoption of a safe system

Note 1: Examples of sanitation steps: waste generation, transport or conveyance of waste, treatment, use of product, application of the waste product for use, disposal, consumers or users of the waste produce.

Note 2: Stakeholders:
- have direct control over some aspects related to wastewater system and use (e.g. regulatory authority);
- have some influence over practices that affect wastewater use safety (e.g. farmer cooperatives);
- are affected by actions taken in the system to protect water quality (e.g. local community); or
- are interested in water quality (e.g. an NGO working with people affected by the system).

Volume 4, Section 10.2.2 of the 2006 WHO Guidelines on the Safe Use of Wastewater, Excreta and Greywater (WHO 2006) provides guidance and examples of stakeholders and stakeholder analysis.

TOOL 1.2

Suggested SSP team membership recording form

NAME/JOB TITLE	REPRESENTING	ROLE IN SSP TEAM	CONTACT INFORMATION

EXAMPLE 1.1

Typical SSP objectives

- To improve public health outcomes from the collection, treatment, reuse and/or disposal of human wastes in both formal and informal settings.
- To increase amenity of public parks by safe use of treated or partially treated wastewater or sludge.
- To ensure products produced using human waste are safe and consistently meet quality requirements.
- To protect the health of consumers of vegetables grown within the SSP boundary, the farmers who use the water for irrigation and the users of parks in contact with grass irrigated with treated wastewater or contaminated river water.
- To safeguard human health, promote the safety of workers and users, and enhance environmental protection.
- To promote national discussion and policy and regulatory changes for risk assessment and management approaches such as SSP.

EXAMPLE 1.2

Example of boundaries and lead organizations

SYSTEM BOUNDARY	LEAD ORGANIZATION	FOR EXAMPLES
A waste stream from generation to point of use, through treatment, and disposal, valorisation and use of the end product. Note: this address the whole sanitation chain	Wastewater utility operator	Worked example: SSP in Newtown, and Examples 1.6 & 1.7
Administrative boundaries (e.g. a city or whole community) Note: if a waste stream is “trans (administrative) boundary” the SSP team should allow all the administrations to work together and coordinate the SSP	Local Authority or community leadership structure	Example 1.3
A business based on waste use	Business owner	Example 1.4 and System map in Example 2.3
A catchment/ boundary (e.g. a catchment-wide SSP as part of an integrated water resource management (IWRM) plan	Catchment Management Authority/ Water Users Association	Example 1.5
A specific product (e.g. as part of a food safety /quality assurance plan for a specific food crop where wastewater or biosolids are used)	Producers association or collective; Control authority	Not illustrated in this manual

EXAMPLE 1.3

Peri-urban town: Karnataka, India

SSP objectives	• To identify sanitation improvements most critical for health that can be taken up for immediate action at the town municipal level in the absence of longer term infrastructure development. • To establish the appropriate partnerships with health and agriculture resource partners to enable implementation of the identified improvements.
Location	Peri-urban town: Karnataka, India, population approximately 25,000.
SSP boundary	The SSP area was defined as the town administrative area. The waste streams included: the open drain/stormwater/sewer system, solid waste collection and transfer system, on-site sanitation systems, septic tank sludge collection and disposal (formal and informal), use of the combined drainage/sewer water for agricultural production (formal and informal).
Lead organizations	The State Water and Sewerage Drainage Board and Town Municipal Council Health Department.

EXAMPLE 1.4

Co-composting business using organic waste and wastewater, Viet Nam

SSP objectives	To provide safety assurances for compost produced and safeguard the safety of workers within the business.
Location	Viet Nam.
SSP boundary	Organic composting business using wastewater effluent. Upstream boundary was public toilets generating the sewage. Downstream boundary: point of sale of organic compost produce and application in the field. Included within the boundary was the on-site wastewater treatment plant. SSP scope did not include the organic collection fraction of the wastes.
Lead organizations	Organic producer (in this case, this was a sub-business unit of the city solid waste company).

Based on SSP experience in Viet Nam.

EXAMPLE 1.5

Indirect agricultural use of wastewater, Peru

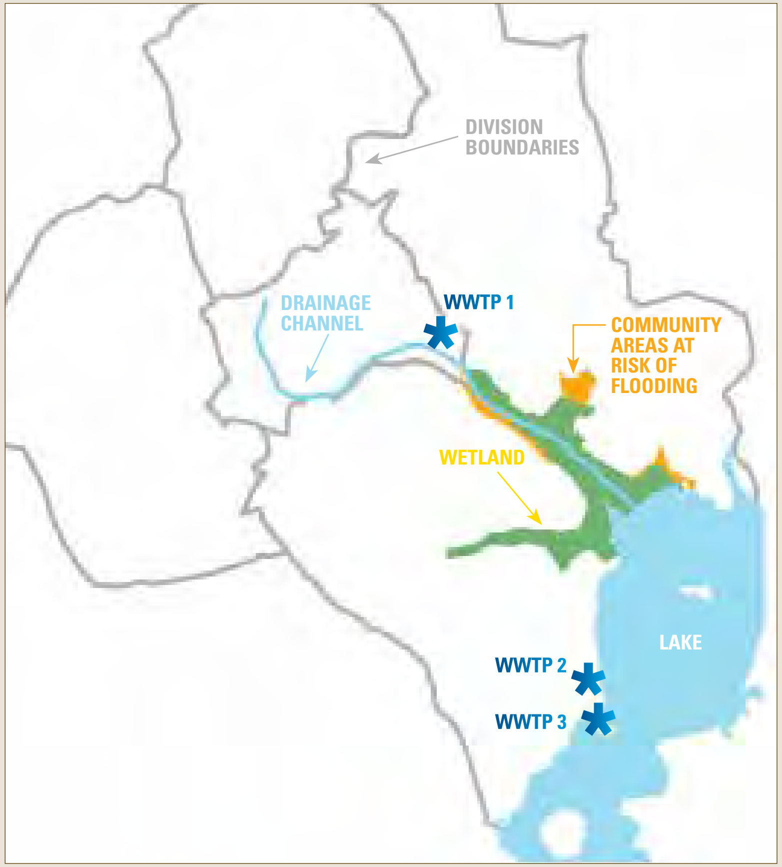
SSP objectives	To prevent diseases related to the consumption of produce irrigated with wastewater and, promote the safety of farm workers and water users. To promote national and regional discussion on how risk assessment and management is reflected in relevant national policies and regulations.
Location	The total area was adjacent to the right bank of the river contaminated with wastewater and excreta from nearby communities. It included agricultural plots, green spaces, private properties and a total farming area of 1,100 hectares irrigated with polluted river water.
SSP boundary	To make the SSP more workable, the SSP boundary concentrated on three specific sites within the area of interest of 23 ha, 330 ha and 250 ha with over 300 landholdings.
Lead organizations	River Users Board (the body that manages the irrigation systems to the area) with technical and scientific support from an academic institution within the boundary.

EXAMPLE 1.6

Urban wastewater system, faecal sludge management and farm application, Kampala, Uganda

SSP objectives	• To safeguard wastewater system workers and the downstream communities, farmers and consumers of the produce. • To protect the drinking-water catchment of Lake Victoria.
Location	Kampala, Uganda.
SSP boundary	Three options for establishing boundaries were considered and compared based on: (1) catchment, (2) wastewater operator's responsibilities and (3) the city administrative boundaries. Although using the catchment boundary was recognized as the ultimate aim, the pilot SSP adopted more manageable operational area boundaries, which still addressed the likely areas of greatest risk. Thus, the pilot SSP boundaries consisted of: the sewer network, treatment plants and the Nakivubo wetland channel (where farming takes place using treatment plant effluent before discharging to Lake Victoria, which acts as the drinking-water supply for Kampala city) (see Figure 2).
Lead organizations	National Water and Sewerage Corporation (NWSC), which is a water utility responsible for provision of water and sewerage services in Uganda, in collaboration with the Kampala Capital City Authority (KCCA).

FIGURE 2.



Urban wastewater system, faecal sludge management and farm application, Kampala, Uganda

EXAMPLE 1.7

Stakeholder analysis, Peru: direct use of treated wastewater for irrigating green spaces of a large public park

The first criterion for choosing the members of the Steering Committee was to include all sectors involved with the use of domestic wastewater. Therefore, representatives from departments responsible for wastewater collection and treatment, health, environment, agriculture and green spaces and the sanitation regulatory body were included on the Steering Committee led by the National Water Authority. In Lima, where priority is given to the use of treated wastewater for irrigating municipal parks, the Municipality of Lima was included as the representative of district councils, which are the water users. Academia was also included as a strategic partner, to monitor the scientific quality of the studies, and to include procedures for the drafting and management of the SSP in their academic programs.

The Steering Committee chose the priority areas to implement SSP and served as a platform to discuss the interoperability of laws and regulations for reuse in the context of city planning priorities.

EXAMPLE 1.8

SSP team members examples

SANITATION STEP	EXAMPLE SSP TEAM MEMBER
Waste catchment area	Representative from major polluters to the waste stream (e.g. upstream factory discharges)
Waste generators	Industry federation
Waste collection and treatment	Sanitation system operator Treatment plant operators (e.g. municipal wastewater treatment plant operators, co-compost plant operators, community management committee of a biogas facility)
Waste transportation	Faecal sludge collection truck operators, operators of piped collection system
Waste application/reuse	Farmers representative, workers representative, local community
All steps from generation to disposal and reuse	Public health official or expert

EXAMPLE 1.9

Team formation experience, Portugal

Background: SSP was developed for the wastewater system of an inter-municipal company responsible for the water supply and sanitation system of seven municipalities with a total population of 160,000 and an area of 3,300 km^2.

Objectives:
The water company's objectives for SSP were to:
- Assess and manage risks in a holistic manner.
- Establish mitigation plans and identify opportunities to improve the quality of service provided in a cost effective and sustainable way.
- Increase robustness of the whole water and wastewater service.
- Promote the use of treated wastewater and sewage sludge.
- Enhance environmental protection.

In addition, an overriding objective of the SSP was to promote national discussion on how SSP could be developed and implemented in Portugal.

To undertake the SSP development, three teams were formed:
- Project coordination team
- SSP team
- Multi-stakeholder team

The three person **Project coordination team** was formed to keep the project on track and to ensure that all the key issues were addressed within the time constraints.

The SSP team comprised representatives from all the departments of the water company, which had direct impact in the management and operation of the wastewater drainage and treatment subsystem, namely: board of administration, quality department, production and treatment department, network management department, commercial (customers) and information technology/geographic information system department, financial and human resources department.

The SSP team coordinator was the water company quality manager who had existing links with all the stakeholders and was also team leader of the company's WSP project.

The multi-stakeholder team was composed of stakeholders who could provide input or support in the successful completion of the project. These stakeholders were chosen as they could affect or be affected by the activities carried out in relation to the sanitation system or because they could be involved in the implementation of the risk reduction measures. They represented differing specialities in policy management, technical know-how and practical experience.

This team included representatives from: environmental authorities, agriculture authorities, regulators, catchment authority, general directorate of health, local health authority, municipality, civil protection and emergency response services, non-governmental organizations, local organizational structures, research partners, farmers associations and water sector association.

A **consultant** assumed the role of the SSP facilitator and technical expertise provider. This involved planning and facilitating meetings, liaising with SSP team and the multi-stakeholder team members, identifying information gaps, compilation and validation of the information collected and providing technical expertise in hazardous events/hazards identification and risk assessment.

Based on SSP experiences in Portugal.

EXAMPLE 1.10

SSP team, Town Municipal Council, India

SSP MEMBER	KEY KNOWLEDGE/SKILLS/ROLES IN SSP TEAM
State Water Supply and Drainage Board -– Senior Manager	**Knowledge/skills:** Technical aspects of water supply, wastewater and drainage contextual information **Role:** • team leader; • provide leadership and link with SSP Steering Committee, and enable all activities on the field; • overall responsibility of all SSP processes; • use SSP improvement plan items to guide funding allocation for municipal sanitation activities.
Town Municipal Council – Environment Engineer and Senior Health Inspectors	**Knowledge/skills:** Environmental health technical aspects, local community/context and municipality organization **Role:** • data collection; • SSP formulation (hazard and risk assessments); • improvement & monitoring planning/operation.
Medical college	**Knowledge/skills:** Epidemiology/health **Role:** • medical and health related technical inputs and training to Town Municipal Council team as necessary; • anchoring the health risk assessment into the SSP
Consultant	**Knowledge/skills:** Environmental Engineering **Role:** • Facilitating organization, technical and other facilitating guidance as necessary

See Example 1.3 for background.

EXAMPLE 1.11

SSP Team, Peru: indirect agricultural use of wastewater

SSP MEMBER	KEY KNOWLEDGE/SKILLS/ROLES IN SSP TEAM
River Users' Board	**Knowledge/skills:** Management of the irrigation system in the agricultural areas adjacent to the River **Role:** • team leader; • to provide information on uses, practices and other information to the team.
Academic institution within in SSP boundary	**Knowledge/skills:** User of the water, technical process information **Role:** • technical process information; • sampling of water, soil, grass.
Farmers within boundary	**Knowledge/skills:** Owners of farm land and on-plot reservoirs **Role:** • to provide information on practices and other information to the team; • to permit sampling of water, soil, vegetables and fish; • implementers of on-farm control measures (e.g. crop selection, withholding periods).
Ministry of Health, and National Environmental Health Agency	**Knowledge/skills:** Monitoring and reporting on health of uses and consumers **Role:** • to provide information and sampling on health related issues; • implementers of training and surveillance for food safety of produce in markets.
International public health UN agency (sponsor of the SSP)	**Knowledge/skills:** Technical cooperation and partnership mobilization in health sector **Role:** • to provide technical support to the team.

See Example 1.5 for background.

MODULE 2

DESCRIBE THE SANITATION SYSTEM

MODULE 2
DESCRIBE THE SANITATION SYSTEM

MODULES

2.1 Map the system
2.2 Characterize the waste fractions
2.3 Identify potential exposure groups
2.4 Gather compliance and contextual information
2.5 Validate the system description

OUTPUTS

- **A validated map and description of the system**
- **Potential exposure groups**
- **An understanding of the waste stream constituents and waste related health hazards**
- **An understanding of the factors affecting the performance and vulnerability of the system**
- **A compilation of all other relevant technical, legal and regulatory information**

Overview

The main objective of Module 2 is to generate a complete description of the sanitation system within the boundary identified in Module 1. A thorough understanding of all parts the sanitation system and its performance requirements supports the subsequent risk assessment process.

Module 2.1 aids understanding of the source and path of waste(s) through the system and is critical in the later assessment of exposure groups at risk.

Module 2.2 covers the microbiological, physical and chemical constituents from all sources, and factors that will affect the performance and vulnerability of the system.

Module 2.3 ensures that an initial classification of exposed groups are identified and related to where and how, within the system, exposure occurs. This is recorded in relation to the mapping in Module 2.1.

Module 2.4 includes collection and documentation of the context in which the system exists; this includes legal and regulatory requirements, historical monitoring and compliance data and information on climate, land use, cultural practice, demographics, the likely concentrations of pollutants and pathogens, and the efficiency of system and system components to reduce the risks. If any discrepancies are identified between existing requirements and potential health hazards, these should be brought to the attention of the Steering Committee to initiate associated policy dialogue.

Module 2.5 ensures that the system description is complete and accurate. Data requirements and potential institutional gaps (e.g. policy gaps) are identified at this stage.

The outputs of Module 2 should provide sufficient information to allow the SSP team to identify where the system is vulnerable to hazards and hazardous events, and to validate the effectiveness of any existing control measures (identified in Module 3) and the system performance.

Much of the information within this Module may have already been gathered if the system has undergone scientific investigations such as health or environmental impact assessment. If so, findings from these studies can inform all aspects of this and subsequent Modules.

2.1 Map the system

Each SSP system is unique and its description and maps should, therefore, be specific.

The method chosen for mapping will depend on the scale and complexity of the system. For some projects it may be useful to map using a system flow diagram which tracks the path of all fractions of the waste. Where the SSP boundary covers a community or catchment, a geographic map may be more helpful.

System flow diagrams can be a simple engineering schematic joining the various components (see Example 2.1), or a system process diagram which uses standard process flow symbols (see Examples 2.2 and 2.3). In larger systems it may be more appropriate to generate a simplified schematic, referencing more detailed process flow information held in other technical drawings.

The system map should follow the path of all fractions of the waste from the point of generation, at an upstream boundary, to its use or disposal at a downstream boundary. See Stenström et al. (2011) for numerous examples of system maps from on-site sanitation to centralised collection and treatment.

It is important to ensure that the mapping is accurate and not simply a desk-based exercise. For example, to know what contextual information is needed in Module 2.4, the system, waste fractions and the potential exposure groups need to be fully understood. For this reason, site visits should be conducted both as part of the mapping exercise and for collecting information required in the following Modules.

At each step, the team should record available quantitative information about the waste stream(s) such as flow rates and the design capacity of each treatment element. It is also helpful to understand the variability of the system (e.g. variability of load, both in terms of quantity and concentration, during heavy rain or flooding). A robust system and system components will be able to absorb variability with limited impact on overall performance.

Guidance Note 2.1 can be used as a check list for Module 2.1.

2.2 Characterize the waste fractions

The mapping exercise in Module 2.1 establishes the path of different waste fractions through the sanitation system.

In Module 2.2, the composition of the waste fractions is characterized. This is an important preparatory step for the hazard identification in Module 3.1 and one that helps to identify factors that will affect system performance, especially the performance of treatment steps. Once the likely components of the raw waste or treated waste are understood, the SSP team can be more focused (in Module 2.4) in collating and collecting data about the health hazards that are likely to be associated with the use of the waste or wastewater.

The waste characterization aims to identify all the different fractions of the waste streams in the sanitation system. For example, the term wastewater is broad, and describes a mixture of different waste components such as domestic wastewater, excreta and urine but can also include temporary stormwater overflows or industrial wastewater. Hence, the system description should define the waste streams into its main components (see Guidance Notes 2.2 and 2.4 for more information on waste fractions and factors to consider and Example 2.4).

2.3 Identify potential exposure groups

The identification of potential exposure groups aims at categorizing people that may be exposed to a particular hazard. This enables a further prioritization both for control strategies as well as for potential exposure groups in the risk assessment under Module 3. Their initial identification and characterization is an integral part of Module 2.

Tool 2.1 shows the usual broad classifications of exposure groups used in SSP. The broad classifications of exposure groups may be added to the system map developed in Module 2.1. In Module 3.2, these broad exposure groups will be refined and defined into sub-groups to aid the detailed hazard risk assessment.

2.4 Gather compliance and contextual information

The team should compile and summarize relevant contextual information that will impact on SSP development and implementation. Where no information is available the team should note the lack of, for example, data, national standards or specifications. The Steering Committee should consider if there is a need for further action in these areas. Information should be assembled for:

- relevant quality standards, certification and auditing requirements;
- information related to system management and performance;
- demographics and land use patterns;
- known or suspected changes relating to weather or other seasonal conditions.

Use Guidance Note 2.3 when collating this information, noting that not all information may be useful and relevant to every system.

Based on the definitions of the waste fractions in Module 2.2, potential health hazards associated with the waste components become evident. For characterizing potential health hazards identified using Guidance Note 2.4; epidemiological and environmental data are preferable where available. For example, if helminths have been identified as a potential health hazard, the characterization is aiming at determining which species are endemic and to what extent. The quality of data needed and possible information sources vary among the different potential hazard categories. Guidance Notes 2.5, 2.6 and 2.7 will assist in identifying and compiling information on the biological, chemical and physical hazards. This will assist in identifying actual health hazards in Module 3.1.

2.5 Validate the system description

Module 2.5 validates the system description through field or other investigations. This should be carried out while completing Modules 2.1 to 2.4 to ensure that the information is complete and accurate. System validation should also provide evidence of the stated system characteristics and system performance (e.g. claimed treatment efficiency).

There are a number of methods to conduct the field investigation such as sanitary inspections and surveillance, focus group discussions, key informant interviews and collection of samples for laboratory testing see Example 2.5). Suitability will depend on the scale and complexity of the sanitation system. Evidence of claimed treatment efficiency could be obtained from a combination of testing programs, technical references or initial process validation data. The system map, system description and waste characterization and factors affecting performance and vulnerability of the system should be updated following validation.

GUIDANCE NOTE 2.1

Checklist of issues to consider when developing a system map

- Include all sources of waste – both point and non-point sources such as runoff.
- Ensure the fate of all used and disposed parts of the waste stream have been accounted for (e.g. use or disposal for crops, fish or animals, soils, surface or groundwater, air).
- Identify all significant existing potential barriers– e.g. detention ponds, septic tanks.
- Include flow rates where known.
- Include capacity or design loading of components where known (e.g. treatment plant flow or loading limits, transfer system capacities).
- Include drinking-water sources where this is relevant to the system or could be affected by the sanitation system.

GUIDANCE NOTE 2.2

Factors to consider when characterizing waste fractions

The source(s) of the waste.

- The main composition of the waste in terms of liquid and solid fractions (see Guidance Note 2.4).
- The potential for accidentally mixed components of the waste that may pose risk (e.g. faecal contamination of agricultural waste, razor blades and batteries in faecal sludge).
- The likely concentration of physical and chemical pollutants and pathogenic microorganismsof the waste.

GUIDANCE NOTE 2.3

Collating compliance and contextual information for system description

When collating information related to potential health hazards, information at the institutional level, population characteristics and environmental determinants, the following should be considered:

a) Relevant quality standards, certification and auditing requirements.

Examples include:

- relevant laws and by-laws;
- effluent discharge or odour regulations;
- planning specifications related to spatial planning of urban areas, vulnerable environmental areas and agricultural/pasture land and restrictions;
- specific national regulations related to agricultural products;
- specific national guidelines for preparedness or disaster planning;
- regulations related to quality monitoring, surveillance and system auditing (not financial);
- certification requirement related to agricultural end products.

b) Information related to system management and performance.

This should provide supporting documentation related to the actual follow-up and enforcement of points noted in a) above. Both documented and non-documented actions should be noted. Consider these points:

- data related to earlier monitoring and surveillance;
- frequency of documentation;
- if faults and/or deviations were followed-up;
- epidemiological data;
- types and amount of products that are produced.

c) Demographics and land use patterns.

Consider these points:

- land use pattern, settlements (and informal settlements) within the area, population and special activities that may impact the sanitation/wastewater production;
- specific equity considerations such as: ethnicity, religion, migrant populations and disadvantaged groups.

d) Known or suspected changes relating to weather or other seasonal conditions.

Consider these points:

- mean variability of the load to the treatment plant over the year;
- seasonal variation of use due to type of crops and harvest;
- additional inflow areas during heavy rain and implications on treatment steps (e.g. need for additional storage ponds);
- changes in usage patterns in time of water scarcity.

GUIDANCE NOTE 2.4

Waste fractions and associated potential health hazards

	WASTE COMPONENTS									
	POTENTIAL BIOLOGICAL HAZARDS					POTENTIAL CHEMICAL HAZARDS		POTENTIAL PHYSICAL HAZARDS		
	Viruses	Bacteria	Protozoa	Helminths	Vector-related diseases	Toxic chemicals	Heavy metals	Sharp objects	Inorganic material	Malodours
Liquid waste fractions										
Diluted excreta (human or animal)	□	□	□	□						□
Urine (human or animal)	□	□	□	□						□
Domestic waste water	□	□	□	□	□			□	□	□
Stormwater	□	□	□	□	□	□	□	□		
River water	□	□	□	□	□	□	□			
Industrial wastewater (Note 1)						□	□			
Solid waste fractions										
Faecal sludge	□	□	□	□	□			□	□	□
WWTP sludge	□	□	□	□	□	□	□	□	□	□
Organic domestic waste	□	□			□					
Inorganic domestic waste						□	□	□	□	
Agricultural waste (crop residuals)	□	□	□	□	□			□	□	
Gardening waste					□				□	
Animal manure/slurry	□	□	□	□	□				□	□
Medical waste	□	□	□	□		□	□	□	□	□
Industrial waste						□	□	□	□	□
Slaughter house waste	□	□	□	□	□		□			□
Construction and demolition waste								□	□	

Note 1: The extent of potential hazards associated with industrial wastewater can vary widely. For example, industrial waste hazards may include pathogens and chemicals. See Thompson et al. (2007) to help identify potential chemical contaminants from industries.

GUIDANCE NOTE 2.5

Compiling biological hazard information

- The control measures defined by the WHO 2006 Guidelines address **bacterial, viral and protozoan** contamination combined without distinguishing between different types and species. An important indicator, however, for assessing pathogen loads in faecally contaminated waste, as well as treatment efficiency of control measures, is the concentration of *Escherichia coli* as a reference organism.
- The presence and frequency of different **helminth** infections is context specific. As the species and concentration of helminth eggs in waste influence the design of control measures, it is important to determine which helminth species are endemic in the study area.
- When waste-fed aquaculture is of concern in the given sanitation system, special attention needs to be paid to food-borne trematodes and schistosomiasis, since transmission of those disease agents involves fish, aquatic plants or exposure to contaminated water (see WHO 2006 Guidelines Vol. 3).
- **Vector-related diseases**
  These are linked to sanitation systems in two ways. Firstly, stagnant parts of drainage systems, treatment ponds or stored waste may serve as breeding sites for insect vectors. This not only results in nuisance to workers and nearby communities but also increases the risk for transmission of vector-related diseases. Secondly, flies can, in addition to breeding in waste, feed on it (e.g. faecal sludge) and subsequently mechanically transfer pathogens to a person or food items.
- Against this background, it is recommended that the SSP team determines which insect vectors are of public health concern in the study area and which vector-related diseases they may transmit.
- **Potential data sources**
  To obtain information on the presence or absence of a specific disease or pathogen, a desktop literature review may give additional information. Information can also be obtained from public health authorities (e.g. Ministry of Health), which have access to the routine health information system, but this information often underestimates disease prevalence and is dependent on the existing medical surveillance system. Consultation of personnel working in health facilities within, or in proximity to, the study area is also a useful way to obtain the information required. Ideally, different data sources are consulted for obtaining reliable information.

GUIDANCE NOTE 2.6

Compiling chemical hazard information

- **Chemical contaminants** in waste are a critical issue since they often pose considerable health risks and are difficult to control/eliminate. Toxic chemicals (e.g. insecticides, pesticides, pharmaceuticals) and heavy metals persist and may accumulate in water bodies, soils and animals. Where toxic chemicals or heavy metals have been identified as a potential health hazard under the waste characterization (Module 2.2), information on the type of chemical pollutants and, if possible, concentrations need to be determined.

  For assessing the suitability of use of a given waste (e.g. treated wastewater), the soil concentration of potential receiving soils needs to be taken into account. See Annex 3 for maximum tolerable soil concentrations of various toxic chemicals based on human health protection.

  Additional comments on chemicals are given in Module 5 – see Guidance Note 5.5.

- **Potential data sources:**
  In the first instance, environmental authorities should be contacted for information on potential data sources (e.g. existing environmental monitoring programmes) on chemical concentrations in different media (e.g. wastewater, river water).

  In addition, existing WWTP may have ongoing monitoring activities that can provide valuable data on chemical hazards. Industrial entities or published references (e.g. Thompson et al., 2007) may also be consulted where industrial waste is of concern.

  In case of poor data availability, the collection and analysis of environmental samples that are obtained from specific waste fractions or environmental media may be warranted.

GUIDANCE NOTE 2.7

Compiling physical hazard information

Physical hazards such as **sharp objects** (e.g. broken glass, razor blades, syringes), contamination with **inorganic material** and **malodours** are often general characteristics of the given waste or linked to a mixture of different waste streams (e.g. razor blades and plastic bags being mixed in faecal sludge). Since the presence or absence of physical hazards has important implications for health risk mitigation, it is important to build up a thorough understanding of the composition and characteristics of the waste as part of the waste characterization.

Additional data sources only need to be consulted based on specific needs detected.

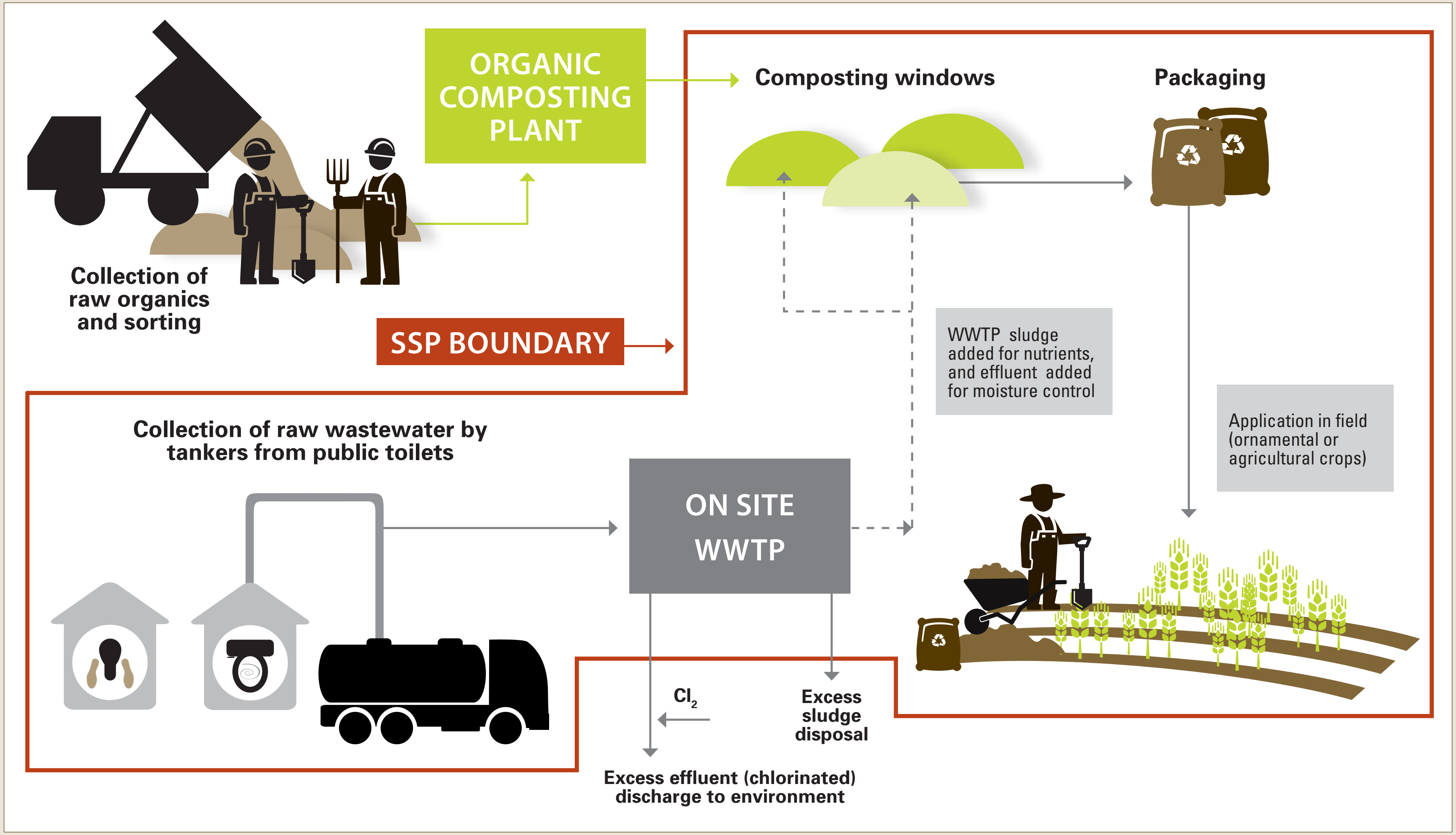
TOOL 2.1

Exposure group categories

SYMBOL	SHORT NAME	SHORT DESCRIPTION
W	Workers	A person who is responsible for maintaining, cleaning, operating or emptying the sanitation technology.
F	Farmers	A person who is using the products (e.g. untreated, partially or fully treated wastewater, biosolids, faecal sludge).
L	Local community	Anyone who is living near to, or downstream from, the sanitation technology or farm on which the material is used, and may be passively affected.
C	Consumers	Anyone who consumes or uses products (e.g. crops, fish or compost) that are produced using sanitation products.

EXAMPLE 2.1

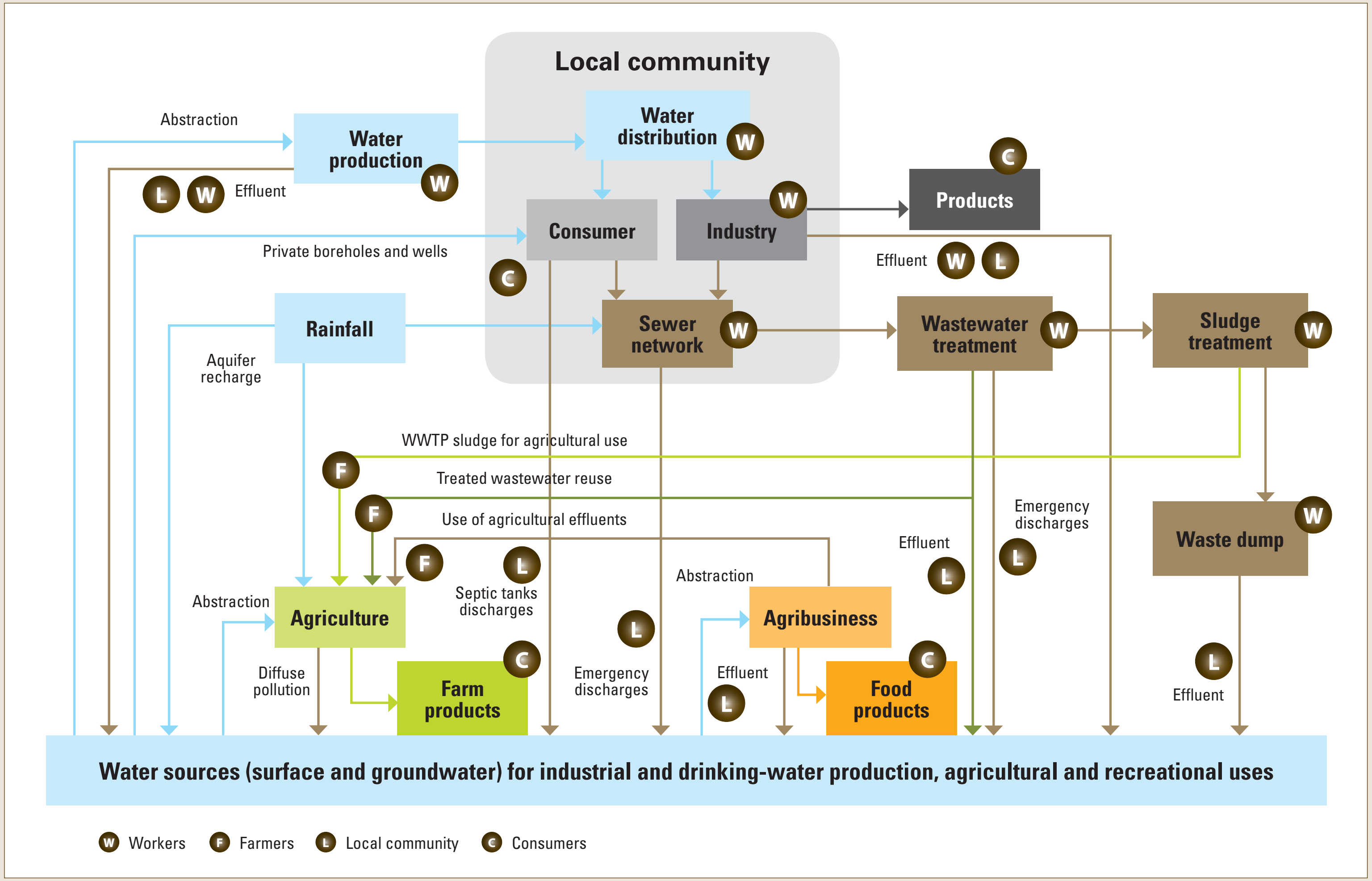
Co-composting of municipal solid waste and faecal sludge



Based on SSP experiences in Viet Nam.

EXAMPLE 2.2

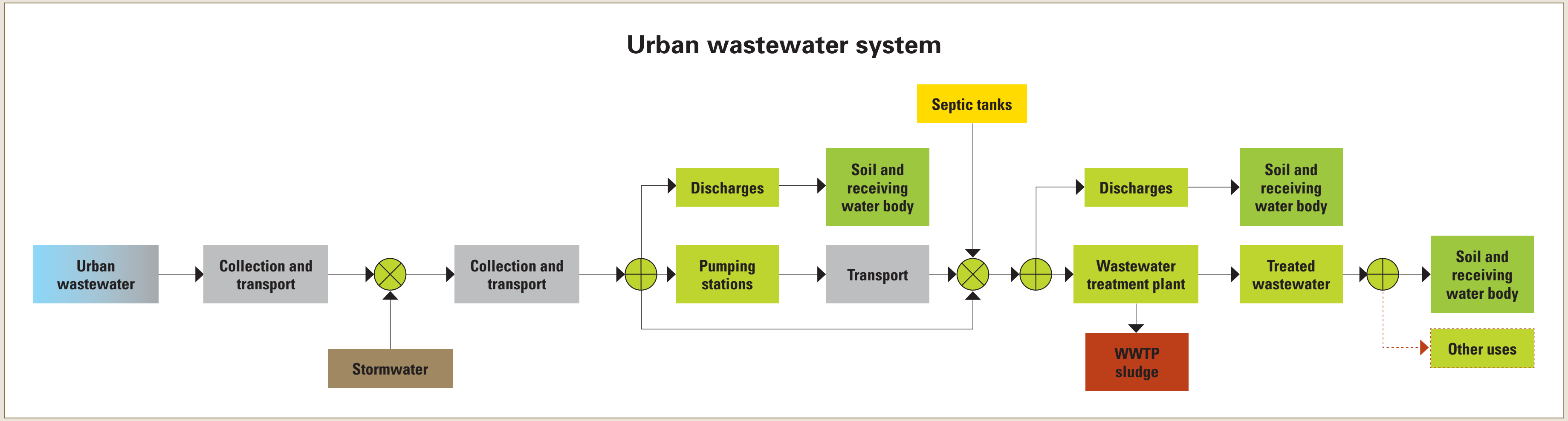
Multiple waste sources mapping, Portugal

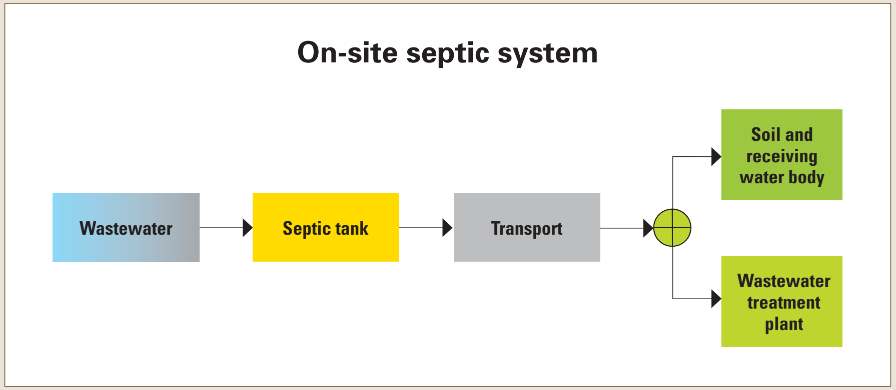


Based on SSP experiences in Portugal.

EXAMPLE 2.2 CONTINUED

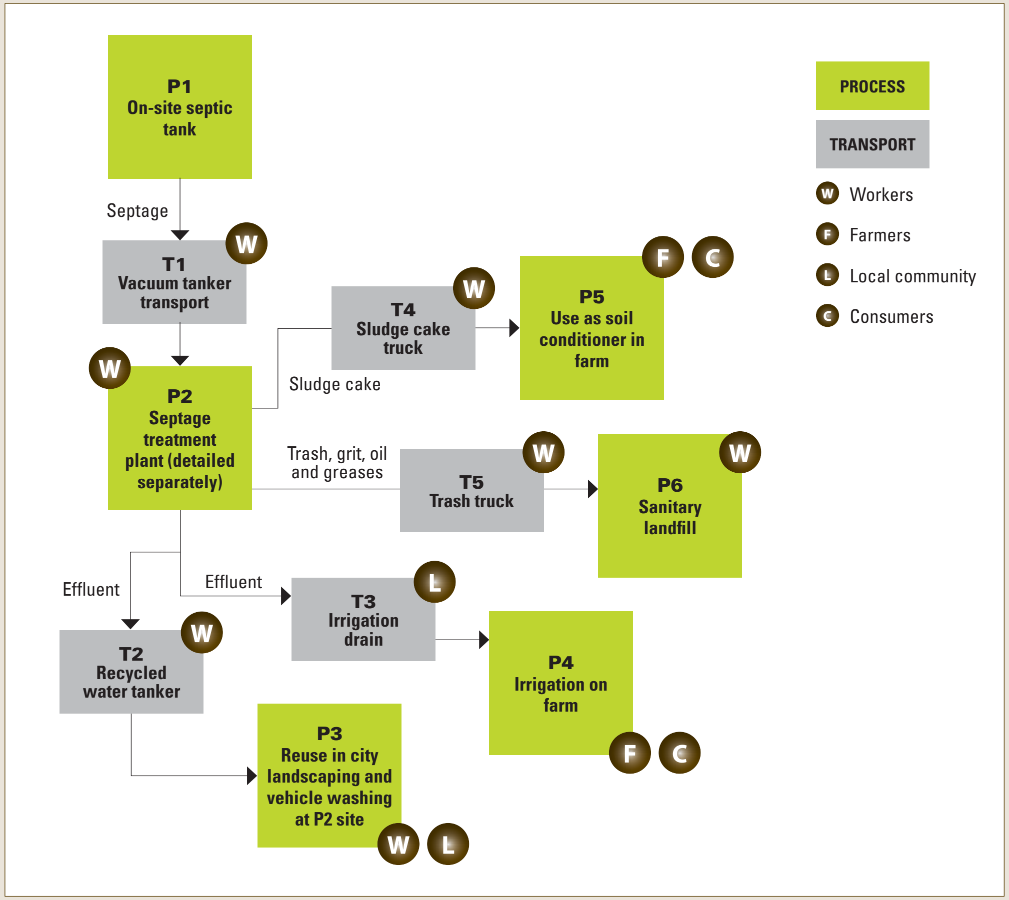
Multiple waste sources mapping, Portugal





EXAMPLE 2.3

Faecal sludge management system, Philippines



Based on SSP experiences in the Philippines.

EXAMPLE 2.4

Waste and hazard characterization from indirect agricultural use of wastewater, Peru

Waste was categorized according to the waste source:

- animal wastes;
- domestic wastewater;
- human excreta;
- urban solid waste;
- agricultural fertilizers and pesticide runoffs;
- mine tailings/releases;
- industrial waste.

Under these classifications, it was then characterized into biological, chemical and physical hazards. For each of these, data were collected and/or described including seasonal variations and comments on unusual events. Some (e.g. mining and industrial) were related to chemical hazards while some were related to microbiological hazards or indicators of these.

Validation was carried out by sampling of water, soil and crops.

See Examples 1.5 and 1.11 for background.

EXAMPLE 2.5

System description validation approach used in Kampala, Uganda

The team mapped and described the system using records and field visits. Additional data collection for validation was done by independent people not directly involved in the initial system description. Network validation data was collected by non-network staff. This ensured confidentiality and avoided bias in the responses and data analysis. Data collectors (at least two) observed the actions of the network operator teams during field visits.

Before and after data acquisition, the data collection tools and results were analysed and discussed within the technical team and collective inputs of opinions were captured.

MODULE 3

IDENTIFY HAZARDS, ASSESS EXISTING CONTROLS, AND ASSESS EXPOSURE RISK

MODULE 3

IDENTIFY HAZARDOUS EVENTS, ASSESS EXISTING CONTROL MEASURES AND EXPOSURE RISKS

MODULES

3.1 Identify hazards and hazardous events
3.2 Refine exposure groups and exposure routes
3.3 Identify and assess existing control measures
3.4 Assess and prioritize the exposure risk

OUTPUTS

- **A risk assessment table which includes a comprehensive list of hazards, and summarizes hazardous events, exposure groups and routes, existing control measures and their effectiveness**
- **A prioritized list of hazardous events to guide system improvements**

Overview

An underlying purpose of all sanitation systems is to protect public health. Module 3 ensures that subsequent efforts and investments in system monitoring and improvements respond to highest health risks first.

Modules 3.1 and 3.2 identify, in detail, who may be at risk and how the risk occurs during operation of the sanitation system, or through the use of its products.

Module 3.3 determines how well the existing system protects those at risk.

Module 3.4 provides a structure to identify and prioritize the highest risks for additional attention.

On completion of Module 3, the SSP team will have identified the hazardous events with the highest risks. For events which have a high risk because there are no existing control measures, or because the existing control measure is not effective, improvement plans to address these risks will be developed in Module 4. For events where existing control measures adequately control the risk, the team needs only to define and conduct operational monitoring to ensure the control measures continue to function as intended (see Module 5).

Guidance Note 3.1 shows some principles to consider when working through Module 3. SSP teams could adopt the formats used in Newtown's SSP Module 3 for recording outputs (see Worked example: SSP in Newtown).

3.1 Identify hazards and hazardous events

Hazard and hazardous event identification helps to focus efforts in the subsequent risk assessment. Example 3.1 shows typical health hazards in sanitation systems. Before commencing on this step it is important to understand the subtle difference between hazards and hazardous events (see Guidance Note 3.2).

The team should identify hazards and their associated hazardous events at each step along the sanitation chain described in Module 2. When doing this, consider:

- hazardous events associated with normal operation of the system (e.g. faulty infrastructure, system overloading, lack of maintenance, unsafe behaviours);
- hazardous events due to a system failure or accident (e.g. partial or full treatment failure, power failures, equipment breakdown, operator error);
- hazardous events related to seasonal or climatic factors (e.g. flood or drought conditions, seasonal behaviour changes by farm workers, seasonal farm workers);
- indirect hazards and or hazardous events (e.g. hazards that potentially affect people not directly involved in the sanitation chain, such as through vermin, vectors or the effects on downstream communities);
- cumulative hazards (e.g. chemicals in soils).

It is suggested that SSP teams define a separate hazardous event for similar events that occur under different circumstances e.g. normal operating conditions and flood conditions (see Example 3.2). This is because the risk profile may be different for each hazardous event.

Hazardous event identification may include consideration of the regulatory and policy shortcomings. For example, release of untreated industrial wastes into the drainage or sewer system may be due (wholly or in part) to lack of enforcement of discharge regulations. In addition to the health risks, environmental side effects may be included.

Hazard identification should be carried out as a combination of desk exercises, using the descriptive information gathered under Module 2, and field investigations using similar tools to those noted in Module 2.5.

3.2 Refine exposure groups and exposure routes

Exposure groups

The broad classification and the location of exposure groups identified in Module 2.3 should be described in more detail.

While some exposure groups, such as waste handlers, are easy to identify, others will be more difficult (e.g. communities accessing nearby groundwater sources, seasonal labour, informal settlements or immigrant populations). Demographics, such as gender, age and potential social exclusion of the exposure groups, should be noted when it will have an impact on the risk associated with the hazardous events. If unsure, include such groups until such time that they can be ruled out.

Consider each hazardous event in Module 3.1 to help identify all groups of people that may be exposed. Tool 3.1 can be used to describe each particular exposure group.

Exposure and transmission routes

The expected exposure (when seen from the human perspective) and transmission (when seen from the source of contamination perspective) routes for the hazardous events and exposures groups should be recorded. This aids understanding of the risk and identification of appropriate controls.

The exposure and transmission routes for excreta-related pathogens may be either primary (through direct contact exposure or short distance airborne transmission) and/or secondary (exposure through an external route, such as consumption of contaminated produce). Guidance Note 3.3 gives common exposure and transmission routes to consider in SSP and more detailed comments on the types of exposure and transmission routes.

The exposure and transmission routes of excreta-related disease are directly linked to the exposure points, and the risk of infection is linked to the potential human host's health risk factors. It is essential to understand these relationships so that the SSP process can result in a decreased risk of disease.

3.3 Identify and assess existing control measures

For each hazardous event identified in Module 3.1, identify what control measures are already in place to mitigate the risk of that hazardous event. Then determine how effective the existing control measure is at reducing the risk of that hazardous event; this can be challenging but information on control measures is provided in Guidance Note 3.4 and Annex 1.

The concept of log reduction values (as a measure of effectiveness) is used within the relevant risk quantification literature as well as the 2006 WHO Guidelines and this manual. For an introduction to log reduction see the Glossary and Guidance Notes 3.5 and 4.1.
When assessing how effective the control is, consider:

1. How effective the existing control measure ***could be*** (assuming it was working well at all times): this is referred to as control measure validation (see Guidance Note 3.6).
2. How effective the existing control measure ***is in practice*** (e.g. bearing in mind the actual site conditions, actual enforcement of existing rules and regulations and actual operating practices).

Assessing how effective the existing control measure could be is often based on literature or detailed technical assessments. Annex 1 and the 2006 WHO Guidelines (Chapter 5 in volumes 2, 3 and 4) provide summary information of potential effectiveness of a range of treatment and non-treatment control measures. Good operational data over a long period can also assist in understanding performance capability.

However, for many control measures, potential and actual performance may vary. For example, a treatment plant may not be properly operated due to operator error or periods of overloading. Some control measures, such as use of personal protective equipment, are dependent on the behaviour of the user. Example 3.3 shows some common control measure failures to consider.

Common sense judgement by experienced members of the SSP team or other professionals may be adequate to validate control effectiveness. Once more data are available, the risks assessment can and should be revisited and a formal validation undertaken if desired and appropriate.

3.4 Assess and prioritize the exposure risk

The hazard identification in Module 3.1 will yield a large number of hazards and hazardous events, some of which will be serious while others will be moderate or insignificant. Module 3.4 establishes the risk associated with each, so that the SSP team can prioritize interventions.

For SSP, different approaches to risk assessment are proposed with varying degrees of complexity and data requirements:

1. Team-based descriptive risk assessment decision.
2. Semi-quantitative risk assessment, using a matrix of likelihood and severity.
3. Quantitative methods (e.g. QMRA).

Any descriptive and semi-quantitative risk assessment approach needs to be undertaken by several individuals within the SSP team, either on an individual basis or as a group work. This helps to increase the objectivity of the risk assessment and produce consolidated ratings.

Quantitative approaches are specialized and would not be generally used by most of the SSP teams at whom this manual is targeted.
Following completion of the risk assessment, the risk levels obtained

should be subjected to a reality check to ensure that they make sense. If in doubt, re-examine the information and rankings.

Team-based descriptive risk assessment

The team-based descriptive risk assessment method involves using the SSP team's judgement to assess the risk of each hazardous event by classifying them according to high, medium, low or uncertain/ unknown risk. These definitions can be defined by the SSP team or those given in Tool 3.2 can be used. However, the principle of safeguarding public health should never be compromised in any definitions.

If the team-based descriptive approach is used, the team may choose to conduct a semi-quantitative risk assessment in the next revision of the SSP. In either case, it is important to record the basis of the decision as this acts as a reminder to the team and/or an auditor or reviewer, on why a particular decision was taken at the time.

Semi-quantitative risk assessment

A more rigorous approach is the semi-quantitative risk assessment. This is appropriate for organizations in well-defined regulatory environments, SSP teams that are already familiar with HACCP or WSP methodology, or SSP teams working on the second or later revision of the SSP process.

The semi-quantitative method requires the SSP team to assign a likelihood and severity to each identified hazardous event using a risk matrix to arrive at a risk category or score. A suggested risk matrix is provided in Tool 3.4. The SSP team needs to work with agreed definitions of likelihood (e.g. what is meant by unlikely, possible and likely) and severity (e.g. minor or major) and apply them consistently (see Tool 3.3). When assessing the severity, consider the contents and concentration of the waste (determined in Module 2) as well as the magnitude of associated health outcomes.

The SSP team may choose to develop its own definitions for likelihood and severity based on the system and local context. The definitions should include aspects related to the potential health impact, regulatory impacts and impacts on community or customer perceptions. However, the principle of safeguarding public health should never be compromised in any definitions.

Guidance Note 3.7 provides a checklist for the risk assessment process. The team should summarize the highest risks. These will be addressed in the improvement actions selected in Module 4.

More sophisticated risk assessment approaches may be applied, taking into account, for example, potential increases in incidence and the number of people affected.

Annex 2 provides summary statements on microbial health risks related to wastewater in irrigation water. This information will assist SSP teams in assessing the severity of hazardous events related to the use of wastewater for agriculture.

GUIDANCE NOTE 3.1

How to approach Module 3

As Module 3 is conducted, SSP team members need:

- A technical understanding of the various components of the system – how they work, both in theory and in practice.
- An appreciation of the transmission routes that may lead to infection or incidence of disease.
- An inquisitive mind: consider:
  - How could the hazard lead to an incidence of a disease or other health impact?
  - How has it done this in the past?
  - Is the hazard ever-present or is it only related to a specific event?
  - What has gone wrong in the past in the system?
  - What could go wrong?

By reading and applying Module 3, team members will become more confident in these issues.

Although Modules 3.1 to 3.4 are identified as separate steps, in practice, there is considerable overlap between these actions. It is not a simple linear process and it may be an iterative process (e.g. after the initial assessment of hazards and hazardous events, it may be appropriate to adjust the initial assessment once more thought has been given to the types of exposure groups, exposure or transmission routes, and where they are in the system).

When identifying the effectiveness of control measures, some points made in Module 4 may be helpful.

GUIDANCE NOTE 3.2

Hazards versus hazardous events

In a hazardous event, people are exposed to a hazard in the sanitation system. As shown below, with the example of pathogens in raw sewage, one hazard may be realized through multiple hazardous events. Each hazardous event has a different cause thus, for the control of each event, specific approaches to minimize the risk are required. The groups of people exposed to the hazard, may be different for each hazardous event.

A well described hazardous event will include a brief comment on the circumstances or cause under which the event occurs.

HAZARD	HAZARDOUS EVENT	CAUSE OF THE HAZARDOUS EVENT AFFECTING ITS FREQUENCY OR SEVERITY	APPROACHES TO CONTROL THE HAZARDOUS EVENT	PEOPLE GROUP EXPOSED TO THE HAZARD
Pathogens in raw sewage	Exposure to raw sewage from overflow of a sewer pipe in high rainfall event	• Conveyance system undersized for rainfall events • Lack of screening of overflows	• Design standards to establish overflow frequency • Regular maintenance of sewer system before rainy season	People living adjacent to the sewer or downstream of the overflow
	Exposure to raw sewage during repair and maintenance of a sewage pump	• Pumps in poor condition or unsuitable for the operating conditions resulting in frequent blockages (which affect the frequency of the event) • Poor staff training/ability or equipment • Lack of bypass during maintenance work	• Planned asset maintenance to reduce pump failure frequency • Selection of pump types and screens during the asset creation (design/construction) phase • Personal protective equipment to workers • Standard operating procedures • Design standards of pump stations	Sewage maintenance workers

GUIDANCE NOTE 3.3

Common exposure and transmission routes to consider in SSP

EXPOSURE AND TRANSMISSION ROUTE	DESCRIPTION
Ingestion after contact with wastewater/ excreta	Transfer of excreta (urine and/or faeces) through direct contact to the mouth from the hands or items in contact with the mouth including ingestion of contaminated soil via contact with hands (e.g. farmers or children).
Ingestion of contaminated groundwater/ surface water	Ingestion of water, drawn from a ground or a surface source, which is contaminated from wastewater or excreta/sludge including unintentional ingestion of recreational waters by swimmers/bathers.
Consumption of contaminated produce (vegetables)	Consumption of plants (e.g. lettuce) that have been grown on land irrigated or fertilized with a sanitation product.
Dermal contact with excreta and wastewater	Infection where a pathogen (e.g. hookworms) enters through the skin via the feet or other exposed body part following contact with wastewater, excreta, open defecation, contents of leaking sanitation technologies or during operation (e.g. pit emptying).
Vector-borne with flies/mosquitoes	Transmission routes include the mechanical transfer of excreta by flies to a person or food items, and bites from a mosquito or other biting insects which could be carrying a disease.
Inhalation of aerosols and particles	The inhalation of micro-droplets of water and particles (which may not be noticeable) emanating or resulting from a sanitation technology, which may carry a pathogen dose.

Notes: Primary transmission includes direct contact with faeces or faecally soiled surfaces, and also person to person contact which, in this context, relates to personal hygiene. Secondary transmission includes, vehicle-borne (food, water etc.), and vector-borne. Vehicle-borne transmission is through contamination of, for example, crops or water sources. Vector-borne transmission is mainly through creation of breeding sites of the vectors. Airborne transmission may also occur, for example during wastewater irrigation.

Based on Stenström et al. (2011).

GUIDANCE NOTE 3.4

Control measures

Control measures are any action and activity (or barrier) that can be used to reduce, prevent or eliminate a sanitation-related hazard, or reduce it to an acceptable level. A barrier is a part of the conveyance, transport, treatment or handling chain that substantially reduces the number of pathogens along a pathway. A multiple barrier approach (i.e. the use of more than one control measure as a barrier against hazards) is recommended.

TYPE OF CONTROL MEASURE	EXAMPLES
Treatment	• physical settling (e.g. settling tank); • bacterial process (e.g. activated sludge); • adsorption (e.g. in constructed wetlands); • biological inactivation (e.g. composting); • chemical inactivation (e.g. sludge drying (controlled by of pH, temp) and disinfection).
Non-treatment	• crop selection; • irrigation type; • withholding times; • control of intermediate hosts and vectors; • vaccination and preventive chemotherapy.
Non-technical	• use of personal protective equipment; • restricted access to treatment or use sites; • produce disinfection, washing and cooking. Note: Behavioural controls are often in combination with the treatment and non-treatment barriers. Behaviour practices are dependent on individual values and preferences (e.g. fears, phobias, habits), constraints (e.g. cost, time, interest), sense of responsibility, and social-cultural perceptions and practices and can be reinforced with health and hygiene promotion.

Based on Stenström et al. (2011).

Sanitation systems should provide a series of barriers against different types of or hazards. That is, a multi-barrier approach is recommended. Put another way, good sanitation systems provide several controls along the entire pathway to reduce the risks to human health.

In systems in which the waste product is used (e.g. in agriculture or aquaculture), an understanding of the exposure pathways and transmission routes aids an appreciation of control measure effectiveness. For example, if a control measure is impractical, too costly, or socially unacceptable, this will influence its effectiveness even if it is technically effective. Furthermore, an understanding of the exposure pathway helps in determining the effectiveness of the control for a given hazardous event. For example, a barrier for preventing dermal contact with waste is unlikely to be effective for inhalation and vice versa.

Annex 1 provides guidance on the effectiveness of a range of control measures. Module 3 of Worked example: SSP in Newtown also illustrates some of these points.

GUIDANCE NOTE 3.5

Aid to understanding hazard reduction concepts in the guidelines

This information may be helpful as the SSP team examines literature (especially the 2006 WHO Guidelines) to determine the effectiveness of the existing control measures and treatment steps in risk reduction. In water supplies, the concept of faecal indicator bacteria was developed in the late 19th Century to assess the efficacy of water treatment. The presence of bacteria of faecal origin (e.g. *E. coli*) indicates that the water has been polluted by faeces and that it may contain pathogenic faecal bacteria. Conversely, the absence of faecal indicator bacteria indicates that the water is unlikely to contain any pathogenic micro-organisms.

Wastewater is known to be faecally contaminated. Here, the numbers of faecal bacterial indicator organisms is used to assess the reduction of faecal contamination through treatment or other processes, and thereby quantify the risk reduction for exposure to, or use of the wastewater. The log reduction of organisms is used to refer to the reduction achieved.

This reduction of faecal indicator bacteria is a proxy for the reduction of faecal bacterial pathogens, but is not directly correlated with the reduction of viral, parasitic protozoan and helminth pathogens.

In agricultural uses, pathogen reduction targets in the 2006 WHO Guidelines, which are based on viral reductions, provide sufficient protection against both bacterial and protozoal infections. For helminths, however, the WHO Guidelines have specific suggestions using counts of helminth eggs for different exposure conditions.

Guidance Note 4.1 summarizes the specific targets in agricultural uses of wastewater.

Based on Mara (2004) and 2006 WHO Guidelines (Vol. 2, 63-69).

GUIDANCE NOTE 3.6

Control measure validation in SSP

Control measure validation proves the control measure is capable of meeting the specified targets (e.g. microbial reduction targets).

For sanitation systems, control measure validation may mean:
- checking system loading against its design capacity;
- checking literature for performance capability of individual treatment process units;
- checking historical performance under unusual conditions;
- checking the 2006 WHO Guidelines for credited reductions of pathogens for non-technical control measures (e.g. see Vol. 2, Table 4.3 and Chapter 5; Vol. 3, Chapter 5; Vol. 4, Chapter 5).

GUIDANCE NOTE 3.7

Checklist for risk assessment

- Decide on a consistent risk assessment methodology upfront.
- Be specific in the risk assessment and relate it to the hazardous event.
- Treat control measure failure as a separate hazardous event in its own right, with its own likelihood and consequence.

TOOL 3.1

Key questions to assist identifying and refining exposure groups and exposure routes

QUESTION	DESCRIPTION OF QUESTION	EXAMPLE
Exposure group ID	**Give a reference – e.g. W1, C1, L1**	**L1 (Local community group No 1)**
Who are they?	Give a description of who these people are and what they do in relation to exposure. Consideration should be given to vulnerable sub-groups considering age, gender and factors of social exclusion.	ABC village residents and visitors to the stream Female seasonal fruit-picking workers
How many are there?	Give actual numbers, if known, otherwise estimate and give basis of estimate Number of people (individuals) likely to be exposed directly or indirectly.	250 householders (including 90 children) in ABC village
Where are they?	Explain where the exposure occurs within the sanitation system to explain how they might be exposed to hazards.	Recreational use of ABC stream
What they are exposed to?	What contaminant and in what circumstances (e.g. chemical, microbial due to barrier failure, extreme weather etc.).	Microbial contamination when ponds overflow
What is the route of contamination?	Infection route to be considered (e.g. through skin, ingestion of crops, soil or water, intermediate vector).	Dermal contact, ingestion
How often are they exposed to this?	Exposure frequency. Is it every time, daily, weekly or perhaps just once a year? If do not know, have a "guesstimate".	Daily contact during summer months
What dose? See Note	Defines the likely dose of exposure. This depends on the local situation and is sometimes difficult to estimate. The dose will also differ between groups of individuals but an "estimate" is still of value.	Pond water is likely to have: • x *E. coli*/100 ml, and • x Helminth eggs/ litre Assumed inadvertent ingestion is 100 ml

Note The dose question would normally only be relevant for more rigorous quantitative assessments like Health Impact Assessments

Based on Stenström et al. (2011)

TOOL 3.2

Suggested risk category descriptions for the team-based descriptive risk assessment

RISK DESCRIPTOR	NOTES
High priority	It is possible that the event results in injuries, acute and/or chronic illness or loss of life. Actions need to be taken to minimize the risk.
Medium priority	It is possible that the event results in moderate health effects (e.g. fever, headache, diarrhoea, small injuries) or unease (e.g. noise, malodours). Once the high priority risks are controlled, actions need to be taken to minimize the risk.
Low priority	No health affects anticipated. No action is needed at this time. The risk should be revisited in the future as part of the review process.
Unknown priority	Further data is needed to categorize the risk. Some action should be taken to reduce risk while more data is gathered.

TOOL 3.3

Suggested risk definitions for semi-quantitative risk assessment

DESCRIPTOR		DESCRIPTION
Likelihood (L)		
1	Very Unlikely	Has not happened in the past and it is **highly improbable** it will happen in the next 12 months (or another reasonable period).
2	Unlikely	Has not happened in the past but **may occur in exceptional circumstances** in the next 12 months (or another reasonable period).
3	Possible	May have happened in the past and/or **may occur under regular circumstances** in the next 12 months (or another reasonable period).
4	Likely	Has been observed in the past and/or is **likely** to occur in the next 12 months (or another reasonable period).
5	Almost Certain	Has often been observed in the past and/or **will almost certainly occur** in most circumstances in the next 12 months (or another reasonable period).
Severity (S)		
1	Insignificant	Hazard or hazardous event resulting in **no or negligible health effects** compared to background levels.
2	Minor	Hazard or hazardous event potentially resulting in **minor health effects** (e.g. temporary symptoms like irritation, nausea, headache).
4	Moderate	Hazard or hazardous event potentially resulting in a **self-limiting health effects or minor illness** (e.g. acute diarrhoea, vomiting, upper respiratory tract infection, minor trauma).
8	Major	Hazard or hazardous event potentially resulting in **illness or injury** (e.g. malaria, schistosomiasis, food-borne trematodiases, chronic diarrhoea, chronic respiratory problems, neurological disorders, bone fracture); and/or may lead to legal complaints and concern; and/or major regulatory non-compliance.
16	Catastrophic	Hazard or hazardous event potentially resulting in **serious illness or injury , or even loss of life** (e.g. severe poisoning, loss of extremities, severe burns, , drowning); and/or will lead to major investigation by regulator with prosecution likely.

TOOL 3.4

Semi-quantitative risk assessment matrix

			SEVERITY (S)				
			Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
			1	2	4	8	16
LIKELIHOOD (L)	Very unlikely	1	1	2	4	8	16
	Unlikely	2	2	4	8	16	32
	Possible	3	3	6	12	24	48
	Likely	4	4	8	16	32	64
	Almost Certain	5	5	10	20	40	80
Risk Score R = (L) x (S)			<6	7–12		13–32	>32
Risk level			Low Risk	Medium Risk		High Risk	Very High Risk

EXAMPLE 3.1

Typical hazards types in sanitation systems

HAZARD TYPE	EXAMPLES
Microbial pathogens	Bacteria, parasitic protozoa and viruses in wastewater from faecal sources (e.g. *Vibrio cholera, Giardia intestinalis*, Coxsackievirus, Hepatitis E). Helminths (e.g. *Ascaris lumbricoides*, hookworm). Vector-borne pathogens (e.g. dengue virus, *Schistosoma* spp.).
Chemicals	Heavy metals in sludge or biosolids from industrial sources (e.g. arsenic, cadmium, mercury). Herbicides and pesticides. In specific situations compounds relate to crop productivity (e.g. boron).
Physical	Sharps (e.g. needles). Odours. Physical injury to workers from equipment. Skin irritants (these are a mixture of microbial and chemical hazards).

Note: Algal toxins may also occur. Cyanobacteria (also known as blue-green algae) occur widely in lakes, reservoirs, ponds and slow-flowing rivers. Many species are known to produce toxins, a number of which have potential health concerns.

EXAMPLE 3.2

Hazardous events – typical considerations

Hazardous events specifically considered:

- the different sources of wastes identified in the system map;
- seasonal or climatic factors (e.g. flow rate variations, increased toxin chemicals in the dry season, seasonal irrigation demands);
- impacts of upstream urban and industrial development;
- system failures or accidents (e.g. chemical contamination from failure or illegal discharges from industries, damage to irrigation infrastructure results in bypassing of on farm pond treatment step).

See Examples 1.5 and 1.11 for background.

EXAMPLE 3.3

Examples of control measures, their expected control performance and common performance failures

CONTROL MEASURE	EXPECTED CONTROL LEVEL, see note	COMMON CONTROL FAILURE IDENTIFIED THROUGH VALIDATION
Personal protective equipment (PPE).	Barrier to dermal and aerosol contact for workers.	Waste handlers only use PPE during cool season leading to exposure risk during in 7 of 12 months per year.
Waste stabilization ponds.	Treating waste to a specified number of coliforms per 100ml	Poor design, overloading or short circuiting leading to reduced retention times and lower quality effluent.
	Reduction of helminth eggs to less than 1 per litre.	
Irrigation application: Use of localized drip irrigation.	High level of worker protection (2 log reduction potentially credited).	Clogging of the pipes means that workers are potentially exposed to wastewater during repairs.
Irrigation application: Pathogen die-off after last irrigation and before harvest.	Actual log reductions are dependent on crop type and temperature and are site specific.	Inconsistent use in the field in dry conditions when alternative fresh water supply is limited. As the reduction rate is highly variable, if helminth eggs remain viable for long periods (e.g. in cooler weather with little direct sunlight) irrigation water with more than targeted maximum number of helminth eggs is vulnerable to failure of control.
Food preparation methods: Vigorous washing of rough-leafed salad crops.	1 log reduction.	Inconsistent use by householders especially the poor and those with limited water supply.

Note: See Module 4 and Annex 1 for more information on how to judge the effectiveness or the expected outcomes from control measures.

Based on WHO 2006 (Vol. 2 Section 3.1.1 and 5).

MODULE 4

DEVELOP AND IMPLEMENT AN INCREMENTAL IMPROVEMENT PLAN

MODULE 4

DEVELOP AND IMPLEMENT AN INCREMENTAL IMPROVEMENT PLAN

MODULES

4.1 Consider options to control identified risks
4.2 Use selected options to develop an incremental improvement plan
4.3 Implement the improvement plan

OUTPUTS

- **An implemented plan with incremental improvements which protects all exposure groups along the sanitation chain**

Overview

In Module 3, the SSP team identified the highest priority risks. Module 4 allows flexibility in selecting new control measures or other improvements that address these risks at the most effective places in the system. This process helps to ensure that funding and effort targets the highest risks with greatest urgency.

Module 4.1 encourages SSP teams to consider a variety of ways to control risks. These may include short and long term plans, treatment, non-treatment and behaviour options, and a range of locations along the sanitation chain.

Module 4.2 consolidates the options into a clear plan of action.

Module 4.3 implements the improvement plan with action taken by the organization responsible for the respective improvements.

The improvement plan developed and implemented under Module 4, and the monitoring plan developed and implemented under in Module 5, are the central outputs of SSP. If the risk assessment and ranking in Module 3 identifies that there is no need for improvements, proceed to Modules 5 and 6 to define the monitoring and supporting programmes for the system.

4.1 Consider options to control identified risks

From Module 3 the SSP team will have a comprehensive list of hazards and hazardous events ranked according to risk.

The SSP team should consider a range of options to control the prioritized hazardous events in order to reduce the risk level. Having done that, the SSP team documents the chosen method in an improvement plan.

Improvement plans can be:

- capital works (e.g. additional or new treatment plant or process element, fencing of plant for access restriction);
- operational measures (e.g. crop restrictions, longer retention times, vector-control);
- behavioural measures (e.g. improved personal protective equipment, health education, regular medical check-ups, behavioural and protective measures);
- a combination of the above.

Example 4.1 shows types of improvement plans and control measures. Annex 1 gives many examples of reuse-related control measures together with comments on their effectiveness in reducing risks.

Guidance Note 4.1 provides information on multiple ways to achieve pathogen reduction for consumer protection.

When considering control options take into account the:

- potential for improving existing control(s);
- cost of the control option relative to its likely effectiveness;
- most appropriate location in the sanitation chain to control the risk (e.g. at the hazard source, or another point downstream);
- technical effectiveness of proposed new control options;
- acceptability and reliability of the control in relation to local cultural and behavioural habits;
- responsibility for implementing, managing and monitoring the proposed new controls;
- training, communication, consultation and reporting needed to implement the proposed control measure.

Where possible, the root cause of a problem should be addressed in the improvement plan. An important risk based principle is that of preventing the hazardous event or locating the control measure or improvement as close as possible to the source of the risk. This is not always possible. Often a combination of hazardous events may be most effectively managed through a single control in another part of the system.

Example 4.2 illustrates options to consider in agricultural low resource contexts and highlights that in some circumstances, although it may be difficult to select ideal options for short to medium term implementation, actions can (and should) be taken to improve public health. Example 4.3 shows a specific control measure for controlling helminth eggs in agricultural settings.

4.2 Use selected options to develop an incremental improvement plan

Once the most appropriate control measures for each risk have been identified the SSP team can record the planned new and improved controls in an improvement plan. The forms used in Worked example: SSP in Newtown can be used as a template for the improvement plan.

Some risks may need actions from more than one organization represented in the SSP team or other stakeholder. In cases where multiple stakeholders are identified for the implementation of the improvement plan, the Steering Committee (Module 1.1) or SSP lead organization (Module 1.3) should take responsibility for agreeing the outcome of the risk assessments and identifying what actions are required.

In order for improvement plans to be implemented and managed, it is necessary to identify the person or agency responsible for the proposed action, and the proposed timeframes. The different roles and responsibilities related to improvement plant implementation, as well as funding and timelines, are ideally defined under the improvement plan.

The SSP team may also choose to select and implement more affordable interim control measures until sufficient funds for more expensive options are available.

Demonstrations of improvement plan outlines are shown in Worked example: SSP in Newtown, and Examples 4.4 – 4.7.

4.3 Implement the improvement plan

The SSP team should monitor and report on the implementation status of the improvement plan to ensure that action is taken.

GUIDANCE NOTE 4.1

Understanding the multiple barrier approach to guide improvements for agricultural use

As discussed in Guidance Note 3.5, the log reductions of pathogens in wastewater treatment, as well as in any sanitation step, are critical in reducing adverse health impacts. The 2006 WHO Guidelines recommend minimum reductions of pathogens to meet the health-based target of a DALY loss of $\leq 10^{-6}$ per person per year.

Figure 4.1 shows potential target log reductions in the case of agricultural use of wastewater, which can be achieved by combining wastewater treatment with other health protection measures. It shows target log reductions to provide sufficient protection against bacterial, viral and protozoa infections. The total target log reductions depend on the type of irrigation practices, the crops grown and the farming practices.

To protect farmers and their families from excess helminth egg infections, all farming practices (except localized irrigation on high-growing crops), should use irrigation water with less than 1 human intestinal nematode egg per litre, or, typically, if children under 15 years of age are exposed, this should be reduced to less than 0.1 egg/litre (see 2006 WHO Guidelines Vol. 2, 66-68 for more details).

For more detailed information on the reductions recommended for wastewater use in aquaculture or use of excreta, refer to the 2006 WHO Guidelines (Vol. 3 section 4.2 and Vol. 4 sections 4.1 and 5).

Some key concepts behind the 2006 WHO Guidelines and Figure 4.1 are:

1. All exposure groups should be adequately protected. In agricultural uses, this particularly applies to agricultural workers and consumers of the produce.
2. It may not be feasible, initially, to meet target log reductions for farmers and consumers in all circumstances. Improvement plans should aim to incrementally improve the situation.
3. The quality of the irrigation water is especially critical for the safety of agricultural workers, farmers and the crop consumers. With regard to pathogen concentrations, raw wastewater should never be considered safe. Therefore, a sufficient irrigation water quality can normally be achieved by wastewater treatment (see point No. 5 & 6 for further discussion). The log reduction required depends, however, on the farming context as shown in Figure 4.1.
4. As farmers and agricultural workers are especially vulnerable, a range of human exposure controls (e.g. personal protective equipment, handwashing and personal hygiene) are also recommended. Although these health protection measures are expected to have an important protective effect, they have not been quantified in terms of log reductions in the 2006 WHO Guidelines. Particularly in contexts where the microbiological quality of the irrigation water does not meet the target water quality, these controls are especially helpful.

5. There is a wide range of treatment options that can meet the irrigation quality requirements. For example, partial treatment through sedimentation and detention can make substantial improvements in quality, retain most nutrients and is less costly than full treatment. Annex 1 and the 2006 WHO Guidelines (Vol. 2, Section 5) gives a range of treatment options with their likely available log reductions.
6. Dilution (e.g. mixing of raw wastewater with river water) can serve as a means to ensure pathogen log reduction. Large dilution rates will, however, be required to achieve even one log reduction.
7. There are many available options to ensure pathogen log reduction in addition to treatment or dilution. The exposure risks to farmers, for example, are substantially reduced by using localized (drip, trickle or bubbler) irrigation practices. In this case, the quality of irrigation water can therefore be less, compared with surface and spray irrigation. An exception being where localized irrigation is used to irrigate low-growing crops, in this case the microbial target of ≤ 1 helminth egg per litre of irrigation water should also be applied. Note that treatment to ensure satisfactory operation of localized irrigation system will also improve irrigation water quality.
8. Other barriers mainly impact on the safety of produce for consumers. In addition to crop restrictions (i.e. whether the crop is normally eaten raw or cooked), options are: pre-harvest irrigation control (e.g. cessation of irrigation before harvest); pathogen die-off before consumption (providing an interval between final irrigation and consumption); and food preparation measures (e.g. washing, cooking and peeling). Details are given in Annex 1 and in the 2006 WHO Guidelines (Vol. 2, Table 4.3 and Section 5).
9. In combination, all controls should, ideally, achieve or exceed the target log reductions. The term "multiple barrier approach" is used to describe a sequential combination of control measures.

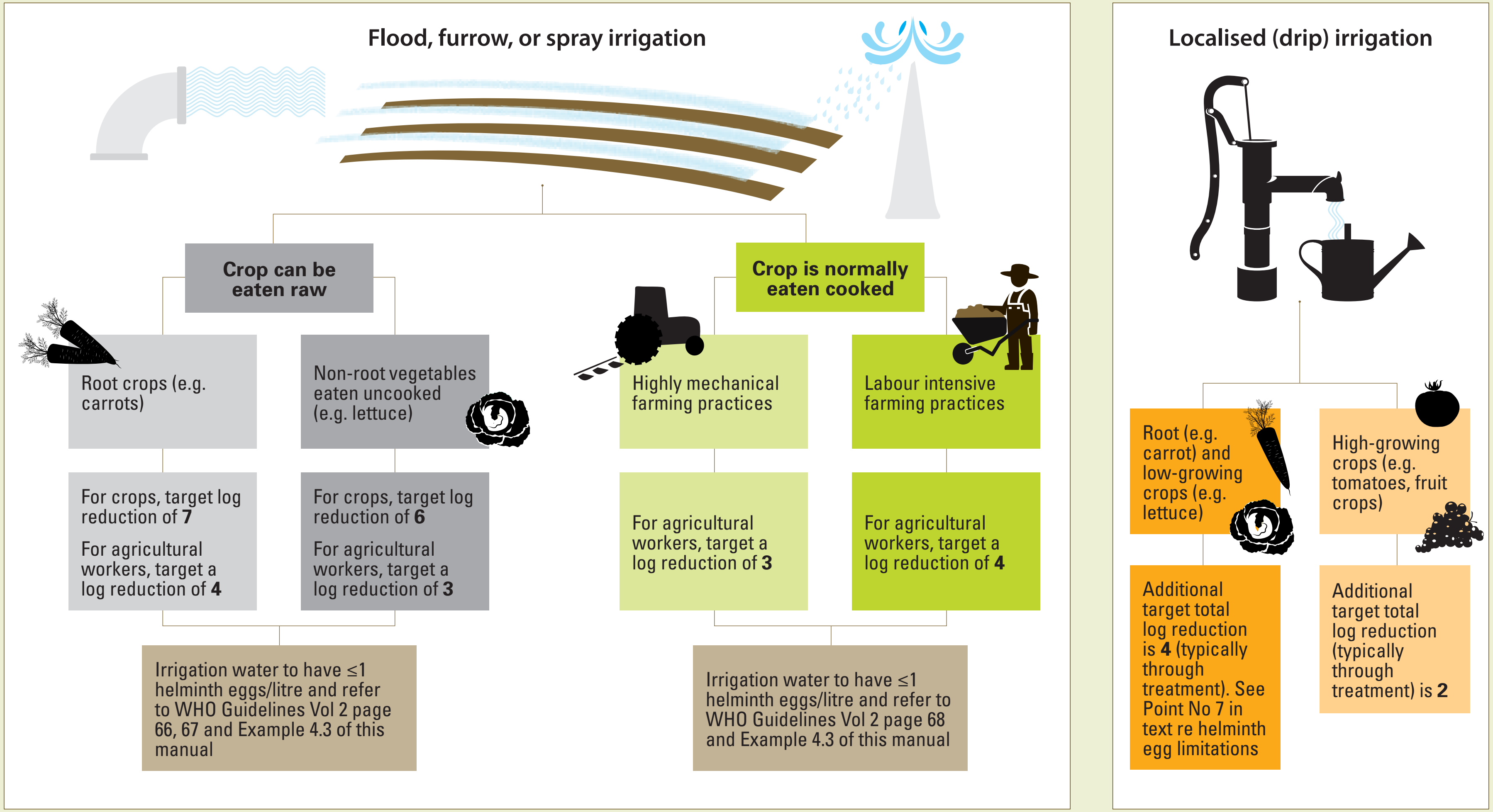
Definitions of key items noted in Figure 4.1 are in the glossary.

A summary of the log reductions achievable from common practices is given in Annex 1.

The Worked example: SSP in Newtown provides some examples of the application of Figure 4.1.

FIGURE 4.1

Irrigation and crop type affects required quality of irrigation water



4

EXAMPLE 4.1

Examples of types of improvement plans

TYPE OF IMPROVEMENT PLAN	EXAMPLES
Control measure: operational	Crop restrictions, irrigation practices
Control measure: behavioural	Washing of hands and feet after finishing farming operations for the day (see Note)
Capital works	Wastewater treatment plant

Note: Soiled clothes worn during farming returned to the domestic domain may also transmit disease.

EXAMPLE 4.2

Improvement plan options in typical labour intensive farming in low resource setting

In this example, current irrigation uses untreated wastewater in furrows. The produce is leafy vegetables for the local market. The lettuce crop is often in contact with the soil, and is generally eaten uncooked. Manual labour intensive farming is practiced.

This is a low resource setting and the wastewater is critical to the livelihoods of the farmers. The farmers value the nutrients in the irrigation water. Centralised wastewater treatment is not considered viable in the short to medium term. Consumers typically wash the produce before consumption.

Figure 4.1 (in Guidance Note 4.1) shows that with the existing practices, the target total log reduction is 6. Of this total, a log reduction of 3 in irrigation water should be targeted in order to protect agricultural workers. The existing practice, however, does not meet the target in relation to microbial (including helminth eggs) irrigation water quality, and agricultural workers are at high risk.

Options considered to protect the agricultural workers include:

- On-farm short-retention-time anaerobic ponds to reduce the helminth eggs and, to some extent, other pathogen loads.
- Drip irrigation (noting that an additional 4 log reduction is still required to fully protect consumers).
- Improved farmer personal protection controls (e.g. personal protective equipment, handwashing and personal hygiene).

Options considered to protect consumers of the produce:

- Pre-harvest irrigation control (e.g. cessation of irrigation before harvest).
- Pathogen die-off before consumption (providing an interval between final irrigation and consumption).
- Washing produce in fresh water before transporting it to the market.
- Education programs to ensure consistent good practice in food preparation.

Given the constraints of this setting, it is recognized that the targets are unlikely to be met in the short to medium term, but a combination of the options noted above can contribute to a lowering of health risks to both farmers and consumers.

EXAMPLE 4.3

Improvement plan options for helminth egg control

Hazard: Helminth eggs

Hazardous event: Exposure to partially treated wastewater in the field by farmers or children (under 15 years) causes helminth infections.

Control measure options and considerations:

1. Wearing shoes or boots can reduce the likelihood of exposure to the hazard. However, because this control measure is often not practical or used by the farmers or children in the field, it cannot be relied upon.
2. Providing some simple wastewater treatment upstream of the irrigation area (e.g. properly sized simple detention pond to reduce the concentration of helminth egg to less than 0.1 egg/litre) can reliably reduce the number of helminth eggs to desirable concentrations (see 2006 WHO Guidelines Vol. 2, 84-86).
3. Regularly providing de-worming medicines to waste handlers (e.g. workers exposed to faecal sludge) can reduce the duration and intensity of infection. In settings where helminth infections are very common, de-worming medicines may also be regularly distributed at community level (e.g. in school children) for reducing prevalence rates.

EXAMPLE 4.4

Organic composting SSP improvement plans, Viet Nam

Some of the key improvement plans for this system are summarized below:

Short term plans:

- Internal training on the importance of workplace health and safety specifically related to the risks identified.
- Review technical operations and procedures to reduce risks related to vacuum tanker operation and addition of wastes to compost from the on-site treatment plant (e.g. re-instatement of broken pump to transfer treated effluent from the sewage plant to the compost piles rather than using vacuum tanker).

Medium/long term plans:

- Improved and increased vehicle and equipment maintenance to reduce the likelihood of mechanical breakdowns (during which workers are more exposed to hazards).
- Upgrade the toilets to reduce risk to workers and the public using the facilities.

Refer to Examples 1.4 and 2.1 for background.

EXAMPLE 4.5

Improvement plans for wastewater use in agricultural and conveyance system, Viet Nam

Context and background:

1) Village area: Water is pumped to the farming area from wastewater canals using a pump station with a capacity of about 40 m^3 per day.

   Manually intensive farming is practiced with a total farming area of 90 hectares. There are also ten fish-raising ponds (also using wastewater canal water). The farming community has about 3,000 people. Vegetables grown include: morning glory and wormwood (year-round), neptunia (from April to August), watercress and water dropwort (from September to March) and houttuynia and pumpkin buds.

2) Wastewater conveyance system from adjoining city is in "wastewater canals". This system conveys untreated wastewater (from domestic and industrial sources) which is used in the farms with no additional treatment.

Some of the key improvement plans for this system are summarized below:

Short term plans:

- Targeted education to farmers and workers aimed at improving the use of appropriate and practical personal protective equipment, and in personal hand and feet washing with clean water during and after the day's work.
- Increased regular mosquito spraying to reduce vector-borne risks.
- Targeted education about the dangers of children playing in and near the wastewater irrigation sites, especially with bare feet.
- De-worming of targeted populations every 6 months.
- Consider improved pre-harvest food protection (e.g. stop irrigation with poor quality water as early as possible before harvest to ensure pathogen reduction).
- Targeted education on safe handling of crops (e.g. vigorous washing or washing with disinfected water especially for those crops eaten raw).

Medium/long term plans:

- Reduce chemical contaminants in wastewater used for irrigation (e.g. improved enforcement of regulations).
- Phased increase in treatment in the upstream system to improve the quality of water discharged to the canal.

EXAMPLE 4.6

Comparison of improvement plans

To prioritize the proposed measures, options were evaluated in accordance to their **potential** to improve the human and environmental health of the system, their **technical effectiveness** and the likelihood of their **being accepted** by those involved. The table below shows the values established for each of these, and the weighting attributed to each category.

Potential	Technical effectiveness	Acceptability
Weighting: 1.5	*Weighting: 1*	*Weighting: 1.5*
High = 3	High = 3	High = 3
Medium = 2	Medium = 2	Medium = 2
Low = 1	Low = 1	Low = 1

Priority score = (potential x its weighting) x (effectiveness x its weighting) x (acceptability x its weighting) Highest priority was given to the options with the highest score.

This allowed the SSP team to prioritize the improvement plans according to financial and resource limitations.

Based on SSP experiences in Peru.

EXAMPLE 4.7

Range of existing and potential measures identified for indirect agricultural use of wastewater in Peru

The system was broken into several headings to classify the existing and potential control options. It was noted that some measures are repeated for different hazards, implying that the same measure can control more than one hazard in the system. For example "controlling discharges into the river" is a valid measure for seven of the eight priority hazards.

River water intake and distribution system:

- Controlling contamination of the river water (e.g. improved industrial and mining practices to improve quality of effluents, improved solid waste collection).
- Controlling discharges of domestic wastewater into the river and controlling pathogens discharged into the river (e.g. fining scheme for non-compliance and domestic wastewater treatment plants).
- Controlling the discharge of excreta and wastewater into irrigation canals (e.g. on-site sanitation systems in adjacent houses).

Irrigation system for green spaces, farms and aquaculture water:

- Controlling water contamination with pathogens (e.g. storage of irrigation water prior to application for irrigation, new wastewater treatment plants in some upstream towns, control of excreta and wastewater discharges into irrigation canals from nearby houses and human settlements).
- Control of pathogen contamination of vegetables and fish production (e.g. storage of irrigation water prior to application for irrigation, improved management of storages to ensure minimum holding times, fining scheme for non-compliance, post-harvest washing of produce).

MODULE 5

MONITOR CONTROL MEASURES AND VERIFY PERFORMANCE

MODULE 5

MONITOR CONTROL MEASURES AND VERIFY PERFORMANCE

MODULES

5.1 Define and implement operational monitoring
5.2 Verify system performance
5.3 Audit the system

OUTPUTS

- **An operational monitoring plan**
- **A verification monitoring plan**
- **Independent assessment**

Overview

Sanitation systems are dynamic. Even the most well designed systems can under-perform and result in unacceptable public health risk and loss of confidence in the service or products. Module 5 develops a monitoring plan that regularly checks that the system is operating as intended and defines what to do if it is not. Operational and verification monitoring provide assurances to the operators, the public and the authorities of adequate system performance.

Module 5.1 regularly monitors control measures to give simple and rapid feedback of how effectively the control is operating so corrections can be made quickly if required.

Module 5.2 periodically verifies whether the system meets the intended performance outcomes such as quality of effluents or products. Verification may be undertaken by the operator or surveillance agency and will be more intensive in situations with greater resource and/or strict regulatory requirements.

Module 5.3 provides additional independent evidence of the system performance and quality of the SSP. Audits can be part of the surveillance functions outlined in the introductory chapter. Audit and certification will be most relevant in countries where such requirements exists (e.g. certification requirements for wastewater irrigated produce).

The outputs developed in Module 5 generate system specific evidence to justify existing operations or the need for ongoing improvements in later iterations of Module 4.

The improvement plan developed and implemented in Module 4 and the monitoring plans developed and implemented under Module 5 are the core outputs of the SSP process.

5.1 Define and implement operational monitoring

In Modules 3 and 4 a range of existing and proposed control measures were identified. The purpose of Module 5.1 is to select monitoring points and parameters to give simple and rapid feedback that key selected control measures are operating as intended and to provide trends over time.

Typically, operational monitoring collects data from:

- simple observations and measures (e.g. flow rate to check on detention times, temperature of composting, observations of on-farm practices);
- sampling and testing (e.g. chemical oxygen demand, biochemical oxygen demand and suspended solids).

Guidance Note 5.1 gives some examples of typical operational monitoring.

Monitoring of all control measures may not be practical. The most critical monitoring points, based on the control of the highest risks, should be selected. The following aspects should be identified for each of the monitoring points:

- parameter (may be measured or observational);
- method of monitoring;
- frequency of monitoring;
- who will monitor;
- a critical limit;
- an action to be undertaken when the critical limit is exceeded.

Critical limits are usually numerical limits based on a parameter measurement. In some cases, qualitative limits are appropriate (e.g. "all odours to be acceptable" or "flies not a nuisance").

SSP teams may use the formats shown in Tools 5.1 and 5.2 to record the operational monitoring plan (see also Example 5.1).

Operational monitoring plans can be implemented by collating the plans into field-friendly monitoring tables or log books.

5.2 Verify system performance

Verification monitoring is done periodically to show whether the system is working as intended and to provide trends over time. Key (critical) points along the sanitation chain should be selected to verify system performance. This type of monitoring usually requires more complicated forms of analysis (e.g. *E.coli*, helminth eggs) than operational monitoring. Verification monitoring can be done by the SSP team or an external authority as part of the surveillance function described in the introductory chapter.

As with operational monitoring, parameters, method, frequency, responsible agency, a critical limit and remedial actions when the limit is exceeded should all be identified.

Compared with operational monitoring, there will be fewer points at which verification monitoring occurs. Verification monitoring focuses on system end points such as effluent water quality, microbial and chemical testing of produce and soils and health status of exposed groups.

Guidance Notes 5.2 to 5.5 provide additional information on monitoring, verification and specialized assessments and are supported by Examples 5.2 and 5.3.

5.3 Audit the system

A system audit may not be viable in the initial stages of all SSP implementations, especially in the absence of regulatory requirements for risk assessment management approaches.

However, audits ensure that SSP continues to contribute to positive health outcomes by checking the quality and effectiveness of SSP implementation. Auditing can be done by internal, regulatory or independent auditors. It should demonstrate that the sanitation safety plan has been properly designed, is being implemented correctly and is effective. Guidance Note 5.7 gives suggestions for key questions to consider in audits. Audits can assist implementation by identifying opportunities for improvement such as the accuracy, completeness and quality of implementation of the SSP outputs, the better use of limited resources and identifying training and motivational support needs.

Auditing frequencies should be commensurate with the level of confidence required by the regulatory authorities. Identifying suitable skilled and experienced personnel for auditing can be challenging.

GUIDANCE NOTE 5.1

Some typical operational monitoring in SSP

Operational monitoring is the routine monitoring of parameters that can be measured rapidly (through tests that can be performed quickly or through visual inspection) to inform management decisions to prevent hazardous conditions from arising.

For sanitation system operators operational monitoring may involve:

- flow rates for waste application;
- actual versus planned duration of withholding periods;
- frequency of waste collection;
- the quantity of waste targeted for use (as this will give some information of the general impact of the waste production);
- checking physical barriers are in place;
- turbidity, pH, biochemical oxygen demand, dissolved oxygen, residual chlorine;
- frequency with which waste handlers are correctly wearing personal protective equipment;
- tracking of hazard-related weather and climate data;
- conducting sanitary surveillance;
- visual inspection of integrity of fences, warning signs;
- visual inspection of waters for relevant insect larvae or snail intermediate hosts.

GUIDANCE NOTE 5.2

Monitoring references in 2006 WHO Guidelines

The 2006 WHO Guidelines provide guidance on typical parameters, frequency and limits for operational and verification monitoring. This can be found in:

VOLUME OF GUIDELINES	RELEVANT SECTION FOR MONITORING
Volume 2 (Wastewater use in agriculture)	Section 4.3 Verification monitoring Table 4.6 Minimum verification monitoring frequencies for health protection control measures Section 6.4 Operational monitoring Section 6.5 Verification monitoring
Volume 3 (Wastewater and excreta use in aquaculture)	Section 6.5 Operational monitoring Section 6.6 Verification monitoring
Volume 4 (Excreta and greywater use in agriculture)	Section 6.4 Operational monitoring Section 6.5 Verification monitoring

Guidance Note 5.3 summarizes some of the verification monitoring recommendations from the WHO 2006 Guidelines for quick reference.

GUIDANCE NOTE 5.3

Quick Reference to verification monitoring recommendations in the 2006 WHO Guidelines

Monitoring microbial performance

- Verification monitoring of *E.coli* and helminth eggs (intestinal and *Schistosoma* spp.) should be conducted at intervals of 3 -6 months at the point(s) of exposure (Note 2).
- Where schistosomiasis is a hazard, workers and local communities should be examined for signs of infection yearly, every two years or every 5 years in high, medium and low prevalences respectively (Note 2).
- Verification monitoring for *E.coli* and helminth eggs (where necessary) in aquaculture ponds should be conducted at monthly intervals if fish or aquatic plants are grown that are routinely eaten raw (Note 3).
- Verification monitoring for skin irritants should be conducted. Inspection for skin diseases in aquaculture workers and others with heavy exposure to the water every 6–12 months (Note 4).
- Testing for viable trematode eggs should *always* be done at the system validation stage unless plant or fish species are always eaten after thorough cooking (Note 1).
- Verification of pond waters for insect vectors every 2-3 months (Note 4).

Monitoring Chemical performance:

Verification monitoring of chemical, concentrations in waste-fed aquacultural products should be conducted 6 monthly by food safety authorities (Note 3).

Note: References in 2006 WHO Guidelines Vol. 3: page 40 (1), page 44 (2), page 42 (3) page 45 (4).

GUIDANCE NOTE 5.4

Chemicals in agriculture and aquaculture and SSP

In agricultural use, the hazards mostly likely to cause diseases are the excreta-related pathogens (including intestinal helminths and schistosomes), skin irritants and vector-borne pathogens. Risks from chemicals are thought to be low and would be difficult to associate with exposure through wastewater use in agriculture because the effects from chemical exposure are usually cumulative over a long time period (2006 WHO Guidelines Vol. 2, 8).

In aquaculture, see 2006 WHO Guidelines (Volume 3 Section 3.3 and Volume 3 Section 4.1.3) for background and guidance on possible verification monitoring in fish and vegetables.

The food-chain transfer is normally the primary route of exposure to potentially hazardous chemical pollutants in wastewater (2006 WHO Guidelines Vol. 2, 73). Annex 3 shows the tolerable concentrations of toxic chemicals in soil, fish and vegetables which may be used in some verification programs.

For inorganic elements, their concentrations in wastewater irrigation soils will slowly rise with each successive wastewater application. However, heavy metal accumulation in crops irrigated with domestic wastewater in India has been found to be lower than permissible levels despite wastewater having been used for irrigation at the same site for about 30 years (Mara 2004, 245).

However for many of organic components, the likelihood is small that they will accumulate in the soil to the computed thresholds concentrations, because the typical concentrations in wastewater are very low More details can be found in the 2006 WHO Guidelines (Vol. 2, Sections 4.6 and 8.1).

National regulations and standards should also be consulted.

GUIDANCE NOTE 5.5

Specialized assessments

Health Impact Assessment

SSP is not intended to be used for planning and designing new large sanitation schemes. In these cases, the planning may be complemented by specialized studies such as health impact assessments (HIA). HIA is an instrument for safeguarding the health of vulnerable communities in the context of accelerated changes in environmental and/or social health determinants resulting from development. The WHO defines HIA as "a combination of procedures, methods, and tools by which a policy, programme, or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population" (European Centre for Health Policy, 1999). HIA embraces an interdisciplinary and multidisciplinary approach with the overarching goal to influence decision-making, so that negative health effects can be minimized and positive health effects enhanced. HIA considers a broad range of determinants of health and health outcomes, and usually combines qualitative and quantitative methods to subsequently guide mitigation measures. Stakeholder involvement throughout the process is an essential feature of HIA.

For the planning and designing of a new large sanitation scheme, HIA can assist in choosing the most suitable sanitation system option from a public health perspective. In addition, HIA systematically identifies potential, and sometimes unintended, health effects of a project throughout its life cycle (i.e. construction, operation and closure). Primary outcomes of the HIA are: (i) inputs into the design of a sanitation scheme; (ii) health impact mitigation and enhancement measures; and (iii) a robust baseline description, which will set the basis for future monitoring and evaluation of public health impacts of the sanitation scheme.

In contrast to SSP, which is primarily conducted by systems operators, HIA is carried out by public health professionals. Further information can be found in Vol. II, Annex 3 of the 2006 WHO Guidelines, and the WHO HIA web site noted in Additional Reading.

Quantitative microbial risk assessment

Quantitative microbial risk assessment (QMRA) is a method that can be used to assess the risk from specific microbial hazards through different exposure pathways. It can be used to complement epidemiological studies for the exploration of disease in a defined population (e.g. farm workers using treated wastewater for crop irrigation). QMRA can also be used as a method of setting health-based targets. These targets define, at a national level, the tolerable burden of disease associated with sanitation systems. At the system level, QMRAs can be used as an assessment and verification tool to model the pathogen reduction required in order to achieve health-based targets.

In most cases QMRA will be beyond the capacity of system operators but may be undertaken by public health specialists. For further information see Haas et al. (1999) and WHO (2011).

GUIDANCE NOTE 5.6

Questions to consider in audits

- Have all significant hazards and hazardous events been identified?
- Have appropriate control measures been included?
- Have appropriate operational monitoring procedures been established?
- Have appropriate operational or critical limits been defined?
- Have corrective actions been identified?
- Have appropriate verification monitoring procedures been established?
- Have those hazardous events with the most potential for problems to human health been identified and appropriate action taken?

TOOL 5.1

Operational monitoring overview plan template

	CONTROL MEASURES TO HAVE A DETAILED OPERATIONAL MONITORING PLAN
SANITATION STEP	Instructions: List the control measures for which a detailed operational monitoring plan is required, and use Tool 5.2 for each of these)
Waste generation	
Waste transport/ conveyance	
Waste treatment/ processing	
Waste use or disposal of by-product	
Consumption or use of the product	

TOOL 5.2

Operation monitoring template

OPERATIONAL MONITORING PLAN IN COMPOST PLANT				
Operational monitoring plan for:				
CONTROL MEASURE SHORT DESCRIPTION				
Operational limits (see note)	Operational monitoring of the control measure		Corrective action when the operational limit is exceeded	
	What is monitored?		**What action is to be taken?**	
	How it is monitored?			
	Where it is monitored?		**Who takes the action?**	
	Who monitors it?		**When it is taken?**	
	When it is monitored?		**Who needs to be informed of the action?**	

Note: If the monitoring is outside this limit(s), the control measure is deemed to be not functioning as intended.

EXAMPLE 5.1

Operational monitoring plan for monitoring technical procedures: composting plant, Viet Nam

OPERATIONAL MONITORING PLAN IN COMPOST PLANT				
Operational monitoring plan for: **MONITORING TECHNICAL PROCEDURES OF WORKERS AND MANAGERS**				
CONTROL MEASURE SHORT DESCRIPTION				
Operational limits (see note)	Operational monitoring of the control measure **Control measure: Treatment plant (waste stabilization ponds) including maturation pond**		When the operational limit is exceeded **Corrective action—**	
100% compliance with technical procedures	**What is monitored?**	Practice and procedures	**What action is to be taken?**	Verbal reminder to staff and record keeping
	How it is monitored?	Observations		
	Where it is monitored?	On-site	**Who takes the action?**	Staff and managers of Quality Assurance Department
	Who monitors it?	Staff and managers of Quality Assurance Department	**When it is taken?**	Within 24 hours
	When it is monitored?	Random visits at least once per month	**Who needs to be informed of the action?**	Monthly reports to quality assurance department

Note: If the monitoring is outside this limit(s), the control measure is deemed to be not functioning as intended.

EXAMPLE 5.2

Verification monitoring sampling programme: composting plant, Viet Nam

SAMPLING LOCATION	SAMPLE NO. /3 MONTH	PARAMETER
Soil sample surrounding public toilets	**3**	*E.coli* Helminth eggs
Sludge at receival tanks of the sludge treatment plant	**2**	
Wastewater sample at the final settling	**2**	
Sediment sample	**2**	
Water sample from pipe head of vacuum tankers in different steps of composting	**2**	
Final compost product	**2**	

Note: The 2006 WHO Guidelines do not provide guidance on the recommended minimum verification monitoring frequency applicable for this example. The local SSP team made its own assessment of the frequency to suit its local context and resources.

EXAMPLE 5.3

Hypothetical verification monitoring plan

	VERIFICATION MONITORING				
SANITATION STEP	**What**	**Limit**	**When**	**Who**	**Method**
Waste generation	Quantity and quality of industrial discharges to sewer system	As per local regulation	Ongoing	Sewerage company or regulator	Annual reports
Waste transport	Number of overflows per year	Depends on local contexts and prevailing background data	Annual	Sewerage company or regulator	Annual reports
Waste transport: Fences and warning signs in critical locations	Cases of accidents, falling into the canal	None	Annual	Sewerage company or regulator	Annual survey
Waste processing	Water quality testing of irrigation water against (e.g. treatment plant effluent water quality) • *E.coli* • Helminth eggs	 ≥ 10,000/100ml ≥ 1/100ml	Twice per month	WWTP operator	Standard testing methods
Waste application	Farmers health status: • % farmers and family member with helminth infections • Occurrence of skin infections	Health limits depend on local contexts and prevailing background data	Annual	District health dept.	Annual survey
Waste application	Chemical contaminants in soil	Soil limits – see Annex 3	Every two years	Dept. of Health or Dept. of Agriculture	Sampling and testing survey
Waste application/timing	Microbial plant concentration of pathogens at harvest and at point of sale	No worm-egg and *E.coli*/ gram in vegetables as per national criteria	Every three months	Hygiene and Food Safety Branch – Health Department	Sampling and testing survey
Produce preparation and consumption	Microbial testing of hygienic food preparation spaces in markets, restaurants and product testing	No worm-egg and *E.coli*/ gram in vegetables as per national criteria	Annual	Hygiene and Food Safety Branch – Health Department	Survey
Produce preparation and consumption	Occurrence at household level of food preparation control measures	No worm-egg and *E.coli*/ gram in vegetables as per national criteria	Annual	Hygiene and Food Safety Branch – Health Department	Annual survey

MODULE 6

DEVELOP SUPPORTING PROGRAMMES AND REVIEW PLANS

MODULE 6

DEVELOP SUPPORTING PROGRAMMES AND REVIEW PLANS

MODULES

6.1 Identify and implement supporting programmes and management procedures

6.2 Periodically review and update the SSP outputs

OUTPUTS

- **Supporting programmes and management procedures that improve implementation of the SSP outputs**
- **Up to date SSP outputs responding to internal and external changes**

Overview

Module 6 supports the development of people's skills and knowledge, and an organization's ability and capacity to meet SSP commitments. Existing programmes (e.g. training) may be reconsidered in light of the extent to which they support the SSP objectives.

Module 6.1 helps to ensure that SSP operation is supported with clear management procedures, programmes of research and training for staff, and communications to key stakeholders especially in larger or complex systems.

Module 6.2 recognizes that SSP works within a dynamic environment. Hence the SSP outputs should be periodically reviewed as new controls are implemented and to analyse new or emerging hazards and hazardous events.

Supporting programmes and regular reviews will ensure SSP is always relevant and responds to the current or anticipated operating conditions.

6.1 Identify and implement supporting programmes and management procedures

Supporting programmes are those activities that indirectly support sanitation safety, but are also necessary for proper operation of the control measures. A key aspect of supporting programmes is communication of health issues with all stakeholders.

Supporting programmes cover a range of activities including training, communication and research, as well as legal aspects such as a programme for understanding the organization's compliance obligations (see Examples 6.1 and 6.2).

Management procedures (see Guidance Note 6.1) are written instructions describing steps or actions to be taken during normal operating conditions and for corrective actions when operational monitoring parameters reach or breach operational limits. These are often called standard operating procedures or SOPs. Additionally, emergency management procedures could also be developed.

In some cases, the lead agency would undertake the supporting programs or allocate specialized aspects to another agency.

6.2 Periodically review and update the SSP outputs

The SSP should be systematically reviewed and revised on a periodic basis. The review will take into account improvements that have been made, changes in operating conditions and any new evidence on health risks related to the sanitary systems. In addition, to scheduled periodic review the SSP should also be reviewed in the following situations:

- after an incident, emergency or near miss;
- after major improvements or changes to the system;
- after an audit or evaluation to incorporate findings and recommendations.

Example 6.3 shows some SSP review triggers used in SSP in Peru.

GUIDANCE NOTE 6.1

Management procedures

All systems require instructions on how to operate the system. Management procedures (e.g. standard operating procedures) and manuals should be available for individual technical components of the system, such as for a pump or treatment process. It is important to have relevant information available and properly stored.

Documenting operating, maintenance and inspection procedures is important because it:

- helps build confidence that operators and backup support know what, how and when to take actions;
- supports consistent and effective performance of tasks;
- captures knowledge and experience that may otherwise be lost when staff members change;
- helps in training and competency development of new operators;
- forms a basis for continuous improvement.

In addition to the technical information needed to run the system, management procedures should be developed outlining the tasks to be undertaken in managing all aspects of the sanitation system, including during emergency situations. The SSP is an important source of information for drafting these management procedures. The SSP team also needs to ensure that the different roles and responsibilities (i.e. who does what, when, where, how and why) for sanitation safety are clearly understood by everyone involved. An efficient, regular review and updating cycle is important.

Also, procedures for routine monitoring and inspection activities and their collected results (see Module 5) are obviously also important management information and need to be documented.

Example management procedures are:

- operation and maintenance schedules;
- procedures for all aspects of the treatment of the system (e.g. screening aeration, filtration, chlorination);
- operational monitoring procedures as identified in Module 5;
- procedures related to managing inputs to the sanitation system;
- schedules and procedures to monitor wastewater quality and reuse application and statutory requirements.

EXAMPLE 6.1

Examples of supporting programmes

- Training programmes for staff (e.g. treatment plant operators, agricultural extension workers, waste handlers and processors etc.).
- Presentation of evidence and results to public and institutional stakeholders.
- Awareness raising and training for key exposure groups to improve compliance for control measures that require behaviour change.
- Provision of incentives or penalties linked to compliance.
- Routine maintenance programmes.
- Public awareness campaigns.
- Research programmes to support key knowledge or evidence gaps.
- Tools for managing the actions of staff such as quality assurance systems.
- Lobbying for an appropriate SSP enabling environment.
- Engagement of stakeholders in SSP.

EXAMPLE 6.2

Supporting programmes: Indirect agricultural use wastewater, Peru

Training

This SSP noted (among other issues) that farmers will require more training. This would address:

- Risks to health and the environment from irrigating with contaminated water.
- The SSP as an instrument for managing the risks identified.
- Application of measures to control the risks involved in the production system.
- Construction of reservoirs as a means of improving the quality of irrigation water.
- Proper management of reservoirs to ensure the desired water quality is achieved.
- Safe production of fish in the reservoirs.
- Efficient and safe irrigation systems for vegetable crops.
- Efficient management of fertilizers and protection of the aquifer.
- Hygienic handling of harvested produce. Washing and handling.
- Support for the water quality and farm produce monitoring program.

Research

Additional research identified included:

- Confirmation of whether the *Ascaris* and *Strongyloides* (threadworm) larvae found in the soil and grass are parasitic on humans.
- Determination of the maximum permissible limits for various soil and grass contaminants found in green spaces and agricultural areas, particularly heat-resistant coliforms and parasites.
- Efficient use of reservoirs for achieving the water quality required for irrigating vegetables, as a function of the holding period at different seasons of the year and effluent management.

EXAMPLE 6.3

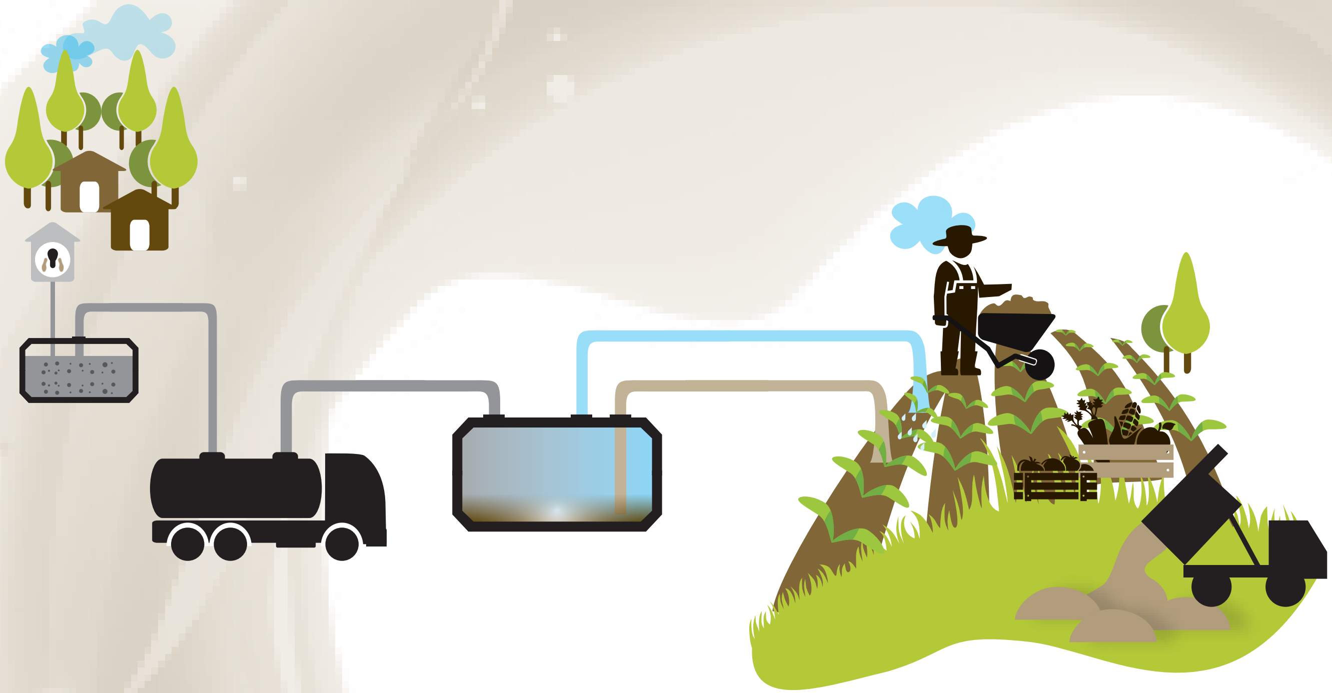
SSP review: Direct use of treated wastewater for irrigating the green spaces of a large public park, Peru

Review after incidents, such as:

- Frequent spillages of raw wastewater and solids from the grit chamber and sludge disposal system.
- Significant escapes of foul-smelling gases that cause a frequent nuisance to visitors to the park, neighbours and the hospital.
- A significant increase in levels *E. coli* and parasites in the effluent from the plant used to irrigate the park's green spaces.
- Excessive accumulation of sludge generated by the plant that cannot be disposed of quickly.
- Death of fish in the boating lake indicating a serious situation and requiring the lake to be closed to visitors.

Review after improvements or significant changes in the system, such as:

- Wastewater treatment process change.
- Any significant change in the irrigation system, such as using the boating lake as a reservoir for treated wastewater.



WORKED EXAMPLE: SSP IN NEWTOWN

WORKED EXAMPLE:
SSP IN NEWTOWN

Overview

This chapter gives a hypothetical case of SSP in a small municipality called Newtown in an imaginary country called the Republic of Sanitola. The Republic of Sanitola is located in the tropical climate zone and is a middle-income country. Newtown is a town on the outskirts of a large metropolitan city with a population of approximately 50,000 people. Water supply is from a surface water source located far upstream of the town. Seasonally heavy rains occur in the area. In recent years, population growth, urbanization and water stress have resulted in an increasing demand for irrigation water and nutrients recovered from wastewater. The reuse of wastewater has, however, resulted in concerns about occupational health of municipal sanitation workers and farmers, as well as the safety of products irrigated with wastewater. Against this background, Newtown's Municipality initiated the SSP process in response to a request from national and city authorities.

The example of Newtown is used to illustrate the SSP Modules, show some potential reporting formats and typical situations in reuse of wastewater in resource limited contexts. It is an abbreviated version of SSP in Newtown and does not cover every detail of Newtown's SSP development experiences.

As every SSP process is developed to suit its own circumstances, its details and conclusions are only illustrative.

An occasional conversational commentary from the SSP team is given to illustrate some issues faced by the SSP team during the plan's development.

Module 1. Prepare for Sanitation Safety Planning

Module 1.1 Establish priority areas or activities

Priority areas:

Newtown was selected as it is considered typical of other towns in Sanitola, it has a relatively good local management capacity, and lessons learnt from Newtown can, largely, be applied to other towns.

Steering Committee:

The Steering Committee comprised Sanitola's Ministry of Health, Municipal Association, Ministry of Agriculture and Newtown's Municipal Council.

It took a lot of effort to get the Ministry of Agriculture on the Steering Committee, but this will be really worthwhile.

Module 1.2 Set objectives

SSP objectives:

Four objectives were established:

- To assure the safety of products irrigated with wastewater for protecting the health of consumers.
- To safeguard the health of farmers and community members who are exposed to wastewater or use it for irrigation purposes.
- To protect the health of informal and formal municipal sanitation workers.
- To assist in prioritizing sanitation investments in Newtown.

Module 1.3 Define the system boundary and lead organization

SSP boundary and waste streams:

Catchment of wastewater treatment plant (including sewer network and faecal sludge collection from on-site facilities), treatment plant, and downstream farming areas.

Lead organization:

Newtown's wastewater operator.

Module1.4 Assemble the team

Key stakeholders:

The farmer's cooperative was identified as a key stakeholder who needs to be part of the SSP team. The full list of SSP team members and respective roles is shown in the table below.

We used a brainstorming session to identify a range of stakeholders and found Tool 1.1 very helpful in deciding the team members.

Newtown Table 1.1 Composition of SSP team

Representatives of	Main role in SSP Team
Sanitation system operator – Senior Manager	Team leader
Sanitation system operator – Operational Manager	Sewage collection treatment plant process and data management
Vacuum tanker operators	Faecal sludge collection and disposal
Farmers' Cooperative	Hazard management of in-farm practices and produce handling to farm gate
Regional Health Department Officer	Public health/food hygiene
Public health/food hygiene	Expert input into the risk assessment
Sanitola School of Public Health - Epidemiologist	Education/communication
NGO working with farmers and local communities	Implications on local water supplies
Water system operator	Implications on local water supplies

Tool 1.2 was used in full, but only the two key columns are included here (i.e. individual names and contacts are not shown).

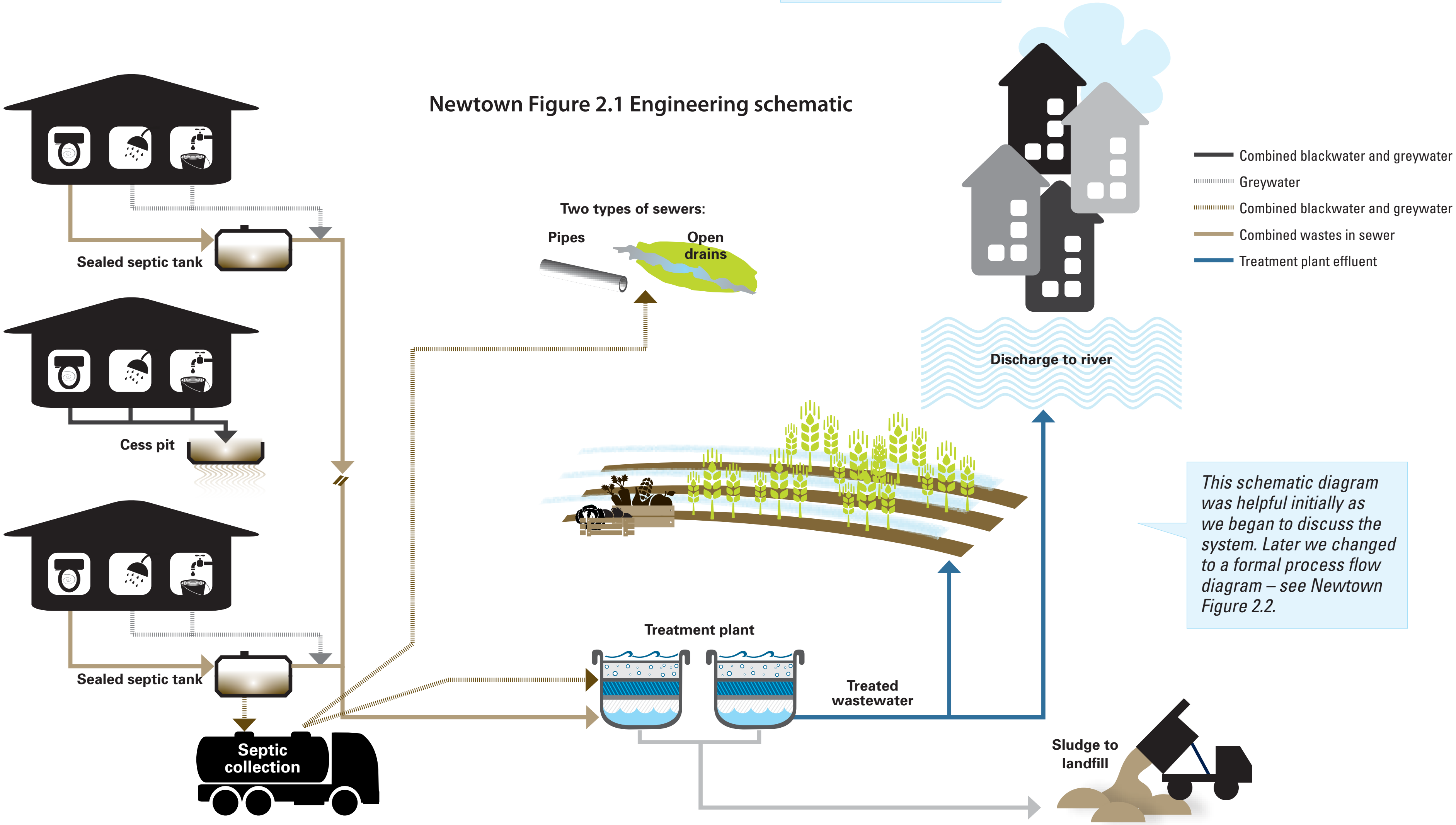
Module 2. Describe the sanitation system

Module 2.1 Map the system

An initial engineering diagram was used to aid in understanding the system.

We initially thought we knew the system quite well, but it was a challenge to collect and collate useful qualitative and quantitive data.

Newtown Figure 2.1 Engineering schematic



This schematic diagram was helpful initially as we began to discuss the system. Later we changed to a formal process flow diagram – see Newtown Figure 2.2.

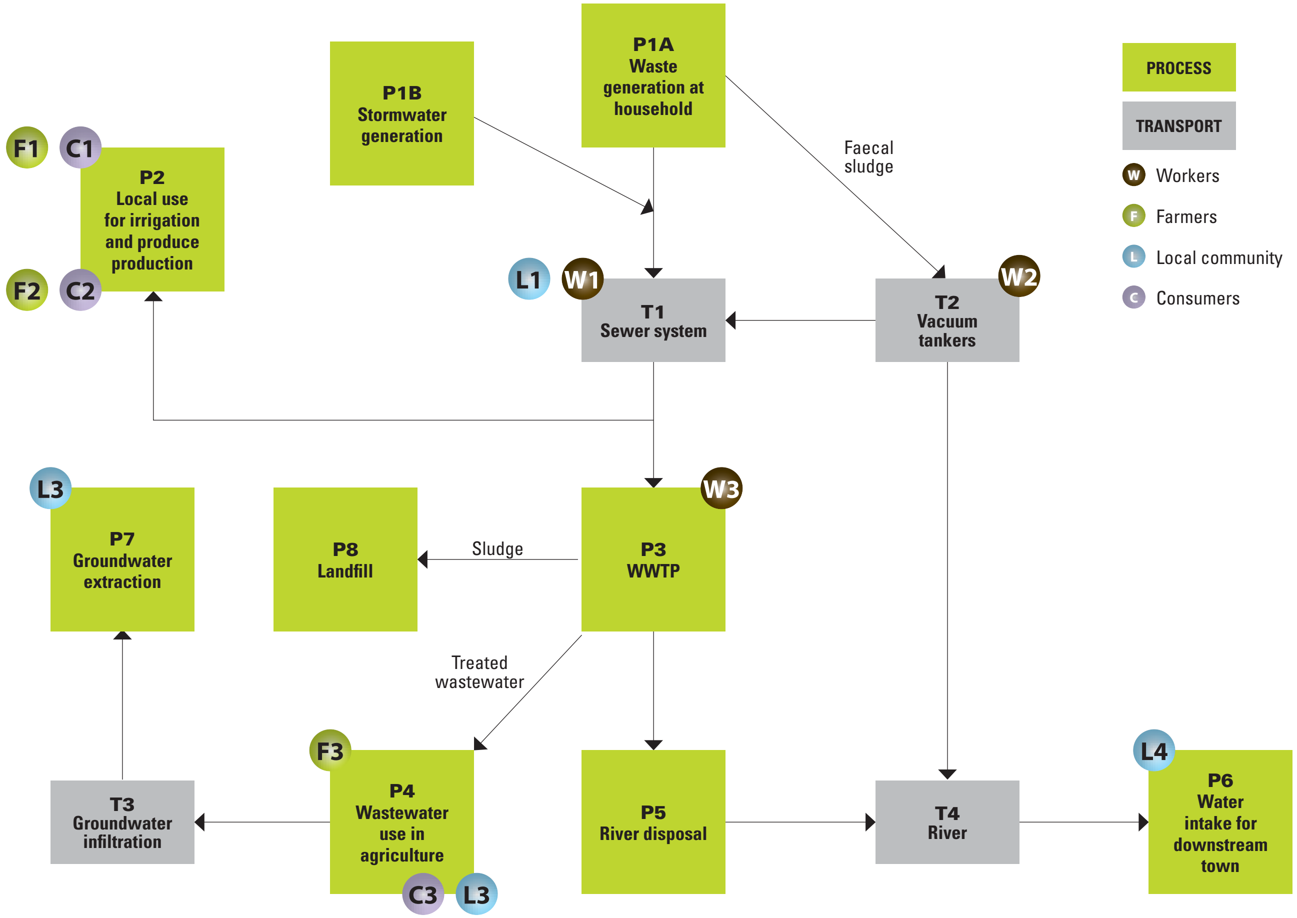
EX

This is the process flow diagram adopted during Module 2.1.

The Process and Transport numbers (P1, P2, T1, T2 etc) helped as we collated the system information.

The exposure groups were added during Module 2.3 and fine-tuned during Module 3.2.

Newtown Figure 2.2 Process flow diagram



P1A and P1B: Waste generation and stormwater generation

Nearly all households (total number: approximately 11,000) have cistern or pour flush toilets that drain into on-site septic tanks. The effluent from the septic tanks drains to a solids-free sewer (also known as common effluent or small-bore) system. Greywater from other fixtures drains directly to the neighbourhood sewer.

Some households have cess pits collecting excreta and greywater. These cess pits have no sewer connection and the liquids drain directly into the groundwater. Open defecation has been eliminated from the area.

Industrial sites do not connect to the sewer except for their own domestic wastes. There is no industry of significance that produces industrial wastewater. The hospital and other health care facilities have reasonable waste management practices that are separate from Newtown's sewage system.

The average dry weather flow at the inlet of the treatment plant is approximately 4,000m^3/day.

Stormwater runoff is generated during the monsoon period from the urban areas. The major sources of contamination affecting the runoff are motor vehicles and solid waste, although animal faecal wastes may also be contributing to contamination. Concentrations and flow rates vary widely over short periods of time.

This description uses references to each of process points noted in the process flow diagram.

T1: Sewer system

Sewage is transported to a centralized wastewater treatment plant. There are two types of sewers:

(1) pipe; this flows mostly under gravity, but there are some small sewage pump stations to lift the sewage to the next gravity pipe.

(2) open drains/channels

Workers from Newtown's engineering department maintain and repair the system.

Both the pipe and the open channels are regularly affected by storm runoff.

This maintenance is not ideal, as they have limited resources.

Overflows periodically occur especially in low-lying areas adjacent to the sewer system.

The drains run through the community and solid waste is often thrown intp the channels by the community or garbage workers. Blockages are common in both the pipes and the channels.

Despite the piped water supply, some houses use shallow wells for water supply.

P2: Local use for irrigation and produce production

Some people (F1) grow water spinach and water bamboo in the channel using raw wastewater. Others (F2) pump the untreated sewage to fruit trees for irrigation.

When we visited the site and spoke with the local people, they informed us that the channel is deliberately blocked for these purposes.

T2: Vacuum tanker septic tank septage collection and transport

Every 5 or 6 years faecal sludge is removed from a householder's septic tank (i.e. about 2,000 properties per year).

This is done with mechanical vacuum tankers. The tankers are unlicensed.

Observations confirmed that the dumping of septic tank sludge is uncontrolled. Some goes to the wastewater treatment plant, but some gets dumped directly into neighbouring drains which flow into the main stream. There have been some minor localized spills reported during emptying but workers do have procedures for dealing with such circumstances.

P3: Wastewater treatment plant

This is a waste stabilization pond treatment system, which is some distance from the local community.

The hydraulic retention time in the first two (anaerobic, facultative) ponds is well below normal design parameters. The last series of ponds (the maturation ponds) are bypassed.

Sludge from the waste stabilization ponds is periodically removed and is stored in the treatment plant site for drying. The dried sludge is infrequently transferred to the Municipal landfill site.

Existing capacity of the treatment plant is approximately 3,000 m^3/day.

Local communities are far away from the treatment plant site.

More detailed analyses of the treatment plant (e.g. components, design capacities, maintenance history, flow records, testing of influent and effluent data) were collected but are not shown here.

We used the local university to provide the treatment process advice throughout the SSP development.

It was frustrating to identify that the maturation ponds were bypassed, but the operational history was lost and there is limited corporate history of the system.

The university staff advised us that the treatment plant in its current mode of operation does not meet the national regulations. As part of Module 3 investigations, they informed us that the pathogen reduction achieved in the treatment plant was about 1.7 log, which is much less than that recommended in the 2006 WHO Guidelines for Safe Use in Agriculture.

P4: Wastewater use in agriculture

Some of the effluent is used by farmers. Irrigation is by:

- Open furrows;
- Some manual application (e.g. scoops & other labour intensive systems like watering cans to a limited extent);
- A trial spray irrigation system is under way, as this is thought to be more water efficient.

The crops grown include salad crops (vegetables eaten uncooked like onions, carrots, lettuce, and capsicum).

There are about 50 farmers.

The farm produce is:

- *consumed by the farmers themselves;*
- *sold to the local community for consumption;*
- *sold to the nearby local city where many thousands of people purchase and consume it.*

This wider market is considered substantial.

The remainder of the effluent (not used in irrigation) is discharged into a small stream.

The farmer's children also help on the farm after school. Focus group interviews showed that the farmers and children do not perceive that there are risks associated with using the water.

Medical records for the farmers and their families were examined and discussion with the farmers (as part of the validation process) was conducted as part of the SSP. This research and discussions with the farmers showed that:

- *Enteric (intestinal) diseases are common, especially after rain.*
- *Worm infections (e.g. human roundworm), are also very common and have a very high prevalence among farmers and their families.*
- *The farmers also get occasional mosquito-related infections (e.g. malaria) and report some skin diseases like contact dermatitis eczema.*

Here are some snippets of additional investigations we carried out to understand some potential health problems as part of Module 2.4.

Health investigations, of the local community living near the farmers found that those living downwind complained about:

- *aerosols drifting from the spray irrigation (there is no buffer zone);*
- *occasional bad smells from the farm;*
- *mosquitoes, which they say come from near the farmer's fields.*

Some of their children from surrounding communities play in the fields and there are some cases of hookworms within in the community.

For the wider population who consume the farm produce, it proved quite difficult to track the farm produce once it leaves the farms as it goes via multiple sellers/agents to reach the city markets.

Consumers do not take any special care in preparing their foods when using produce from this source – in fact, many are not aware of the different sources of the produce they buy. Observations of use indicate that, at best, foods are given a very cursory clean regardless of whether the food is eaten raw (e.g. lettuce or tomatoes, onions, carrots) or is cooked before eating.

The Ministry of Health reported that there is thought to be a persistent problem of Cyclospora especially among visitors to the large city. Recently, it confirmed the presence of Cyclospora spp. oocysts in about 15% of market and farm products. Other infections are suspected but there are no known data available.

P5, T3 and P6: River disposal, groundwater infiltration downstream uses

There is no known formal or informal recreational use of the stream downstream.

About 25 km downstream, a small village (Village A) uses this water as a drinking-water source and irrigation. We had discussions with the Water Supply Division of Sanitola which operates the water supply in the village. This village has a well operated Water Safety Plan (WSP) and they have approached Newtown to improve Newtown's discharge quality as part of Village A's catchment controls in its WSP. They also have a water treatment plant.

P7: Groundwater extraction

The local community, adjacent and near to the farms, uses groundwater as a primary water source as they are outside of the town's water supply system.

P8: Landfill

The sludge from the treatment plant is stored in the landfill site. The site has a dedicated area for dumping of the sludge.

Module 2.2 Characterize the waste fractions

The general nature of the waste is described above. More particularly, the waste stream is comprised of:

- Septic tank effluent – this will comprise primarily of water, excreta and urine. As the majority of the population use water for anal washing, there is limited dry anal cleansing material in this stream.
- Greywater – all domestic waters from bathrooms and kitchens.
- Septic tank sludge – solids and water which settle at the bottom of the septic tank - this has the potential to contain some anal cleansing material, and feminine hygiene products, sharps and other foreign material.
- Stormwater - surface water including urban runoff. It will include a wide range of dilute constituents including, nutrients, metals, pathogens, organic material (oxygen demanding substances), hydrocarbons, animal wastes, and solid waste.

As noted in Module 2.1, there is expected to be very limited health care waste and industrial wastes.

Module 2.3 Identify potential exposure groups

The initial identification of exposure groups is shown in the process flow chart. It is based on the four categories; workers (W), farmers (F), local community (L) and consumers (C) as noted in Tool 2.1.

Module 2.4 Gather compliance and contextual information

Guidance Note 2.3 was used to collate compliance and contextual information. Some of the most important sources of data were: national standards for wastewater treatment plant discharges, treatment plant testing records, health reports and records, municipal town planning data and future growth projections, historical weather records and flooding history and mapping. A summary of the major issues noted is given in the following table.

We extrated the key information from each of these documents relevant to our SSP and presented it in tabular format.

Newtown Table 2.1 Compliance and contextual information

Information sources	Summary of key observations
Standards and regulations	
Sanitola national effluents standard 2010	BOD and SS limits. *E. Coli* limits of 1,000 / 100 ml are given. Does not have helminth egg limitations. Enforcement is limited.
Sanitola biosolid standards and regulations 1998	The reuse of WWTP sludge is prohibited in Sanitola due to concerns about heavy metals.
Information related to system management and performance	
Treatment plant monitoring results for flow and effluent quality	Referred to treatment plant records held by Newtown Sewage Department and occasional Ministry of Environment records. BOD and SS were normally significantly above the national limits and worse in the dry (cooler) season. Average effluent quality is 1.8 x 10^5 *E. Coli* per 100 ml. The data showed declining quality, since records were first started, which was roughly correlated to the population growth.
2012 Ministry of Health: "Epidemiological study on the prevalence of helminthic infections in school-aged children"	A total of 300 school-aged children (9–14 years) were enrolled in a cross-sectional study carried out at the ten major schools of Newtown in 2011. Hookworm and *Ascaris lumbricoides* were the most common helminth infection at 21.9% and 18.4%, respectively. *Trichuris trichiura* infection was detected in 1.5% of the children. No *Schistosoma* eggs were found in any of the stool and urine samples.
Demographics and land use patterns	Limited available space in Newtown, and in-migration from surrounding rural areas is leading to increased population in the lower lying poorer draining areas of Newtown. The populations in these areas are increasingly consisting of vulnerable, elderly and immune-compromised communities.
Changes relating to weather or other seasonal conditions	Seasonal workers from outside areas are employed during harvesting in Sept–Oct period. Wastewater use in the cooler months between December and February is reduced, but the crops at this time tend to be more low-lying.

The Steering Committee is exploring options for an excemption of this regulation for Newtown.

EX

Guidance Notes 2.4 & 2.5 were used to identify potential health hazards associated with the different waste fractions. Based on this preparatory step, additional information was compiled for the identified hazards.

The most important findings for the different types of hazards are summarized:

Biological Hazards:
Different species of viruses, bacteria and protozoa are of concern for the solid and liquid waste fractions. Helminthic infections are common in the local population (prevalence in school-aged children: 18–22%), with hookworm and *Ascaris lumbricoides* being the predominant species. Malaria (*Plasmodium vivax*) is the most important vector-related disease with occasional cases being recorded at the health facilities.

Chemical Hazards:
Data from the national environmental monitoring programme show that the concentration of toxic chemicals such as heavy metals are below national and international reference values in Newtown's surface waters. This reflects the absence industry in the catchment.

Physical Hazards:
Malodours deriving from the different waste fractions are the most important physical hazard present.

Module 2.5 Validate the system description

Validation tools included focus group discussion with farmers and consumers, technical treatment references related to the treatment plant, sampling and testing.

The information given above is after the validation process.

We used the civil engineering department of the university to undertake some tests of influent and effluent, as well as doing a technical review of the treatment plant as part of system validation. The health department reviewed local health statistics to understand potential health concerns and, as part of a validation exercise, conducted some focus group discussions (some of which are noted above).

Thinking in terms of liquid and solid waste stream (as suggested in Guidance Note 2.4) made us realize that we need to better understand the process used, and the regulations related to the sludge occasionally removed from the waste stabilization pond as part of maintenance operations.

We noted that sludge produced from municipal treatment of municipal wastewater is not discussed in the 2006 WHO Guidelines. We referred to national regulations for its safe use and disposal. It noted that the sludge had to be disposed of in an approved landfill site (which Newtown operates) but that it has to be stored on-site for two years before being dumped.

Module 3. Identify hazardous events, assess existing control measures and exposure risks

Module 3.1 Identify hazard and hazardous events

A sample of the outputs of Module 3.1 is given in the Newtown risk assessment table (Newtown Table 3.3).

Module 3.2 Refine exposure groups and exposure routes

As part of the development, each exposure group was refined in more detail. Tool 3.1 was used as part of this (but is not shown here), and as a result, the exposure groups identified in Module 2.3 were split into several sub-groups.

Newtown Table 3.1 Exposure groups

Exposure group: Workers (W)		
No.	Exposure sub-category – Those who:	Individuals
W1	Maintain the sewer systems	20
W2	Collect and transfer faecal sludge	12
W3	Operate the plant	10

Exposure group: Local community (L)		
No.	Exposure sub-category – Those who:	Individuals
L1	Live adjacent to the open drains	5,000
L2	Live adjacent to farms using treatment plant effluent	2,000
L3	Live adjacent to treatment plant and use groundwater	500
L4	Village downstream	10,000

Exposure group: Farmers (F)		
No.	Exposure sub-category – Those who:	Individuals
F1	Informally use the drains to grow crops	50 + families
F2	Pump the water from drains to irrigate fruit trees	50 + families
F3	Farmers using the treatment plant effluent	50 + families

Exposure group: Consumers (C)		
No.	Exposure sub-category – Those who:	Individuals
C1	Consumer crops grown in wastewater by F1 farmers	> 5,000
C2	Consume fruit irrigated with wastewater by F2 farmers	> 5,000
C3	Consumer products irrigated with wastewater by F3 farmers	>> 100,000

EX

Module 3.3 Identify and assess existing control measures

The table below gives examples of some of the control measures in the Newtown's sanitation SSP. These illustrate some of the points in Guidance Note 3.4.

Newtown Table 3.2 Control measures

Sanitation step	Type of control measure (Guidance Note 3.4)	Example control measures currently in place in Newtown SSP with comments (note that comments are specific to the Newtown SSP)
Transport or conveyance	• Non-technical	• Personal protective equipment issued for workers (e.g. boots and gloves) (although its use has not been observed).
	• Non-technical	• Sludge transport vehicles: handwashing and washing of equipment after emptying activities is generally practiced.
Treatment or processing	• Treatment	• Waste stabilization pond (although, in Newtown, this it is not properly functioning).
	• Non-treatment	• Site is fenced.
Use of produce or product	• Non-treatment	• For produce from fruit trees grown by local communities, adjacent to the open drains/ channels, who use the untreated water for fruit tree irrigation: Although the produce (fruit) is eaten raw, it grown at high level and the irrigation system does not use spray irrigation so the crops should have low exposure to raw wastewater but, for example, if picked fruit is stored on ground this may add to its contamination.
	• Non-technical	• Some crops from the main farming area are cooked before being eaten.
Farmers (waste application methods)	• Not applicable	• Little existing control in place especially considering the poor quality of the irrigation water used.
	• Non-technical	• Some of farmers occasionally wear boots.

For issues related to farmer and consumer protection, Guidance Note 4.1 was used, thus: farming type is "flood, furrow or spray irrigation", crop type is "crops can be eaten raw" and "non-root types vegetables eaten uncooked". Therefore the total target log reduction is 6 and, of this total, to protect agricultural workers a log reduction of 3 is targeted.

This was key information used by the team in assessesing existing risks and in developing improvement plans in Module 4.

A sample of the outputs of Module 3.3 are given in Newtown's risk assessment table.

Module 3.4 Assess and prioritize the exposure risk

A semi-quantitative risk assessment process was adopted using the matrix and definitions in Tool 3.3. Refer to the risk assessment table (Newtown Table 3.3), which gives some samples of hazards, hazardous exposure events, hazard type, exposure route, existing control measures etc.

Newtown Table 3.3 Newtown's risk assessment table

Sanitation step	Hazard identification				Existing control(s)		Risk assessment Allowing for the existing control L=Likelihood; S=Severity; R=Risk level				Comments justifying risk assessment or effectiveness of the control
	Hazardous event	Hazard	Exposure route	Exposure groups	Description of existing control	Validation of control	L	S	Score	R	
T1: Sewer system	Exposure to raw sewage in open drains during maintenance activities	All microbial pathogens	Ingestion	W1	Nil (personal protective equipment not used)	n/a	5	4	20	H	Gloves not observed in use during site visits
		Hookworm	Skin penetration	W1	Boots worn, no gloves	Visual and survey	3	2	6	M	Adult hookworm infection usually results in minor health effects
T1: Sewer system	Exposure to raw sewage during pump and pipe repair procedures	All microbial pathogens	Ingestion	W1	Nil	n/a	3	4	12	M	Gloves and handwashing not observed during site visits
		Hookworm	Skin penetration	W1	Boots worn, no gloves	Visual and survey	2	2	4	L	75% wear boots. Adult hookworm infection usually results in minor health effects
T1: Sewer system	Exposure to raw sewage in open drains when playing	All microbial pathogens	Ingestion	L1	Nil	n/a	4	4	16	H	Some children observed to play in the drains
		Hookworm	Skin penetration	L1	Nil	n/a	4	4	16	H	Some children observed to play in the drains. Hookworm infection can cause health effects, particularly in younger age groups. While most will feel minor health effects, some may experience illness. Consequently, the moderate severity category was selected.
T1: Sewer system	Falling into open drain resulting in injury	Injury to the body	Falling into open drains	L1	Nil	n/a	2	8	16	H	A child injured in the drain has been reported

Note: This Table is illustrative only of the hypothetical Newtown SSP – The steps and linked hazard identification and scoring may not be representative of other systems.

EX

Newtown Table 3.3 Newtown's risk assessment table cont.

Sanitation step	Hazard identification				Existing control(s)		Risk assessment Allowing for the existing control L=Likelihood; S=Severity; R=Risk level				Comments justifying risk assessment or effectiveness of the control
	Hazardous event	Hazard	Exposure route	Exposure groups	Description of existing control	Validation of control	L	S	Score	R	
T1: Sewer system	Exposure to raw sewage due to overflowing drains during flood periods	All microbial pathogens	Ingestion	L1	Nil	n/a	5	4	20	H	
		Hookworm	Skin penetration	L1	Nil	n/a	5	4	20	H	Hookworm infection can cause health effects, particularly in younger age groups. While most will feel minor health effects, some may experience illness. Consequently, the moderate severity category was selected. The Likelihood is related to flood conditions as defined in the hazardous event.
T1: Sewer system	Falling into open drains during flood periods	Injury to the body, including drowning	Falling into open drains	L1	Nil	n/a	3	16	48	VH	A child drowned in the drain during a flood five years ago.
T1: Sewer system	Falling into drains during maintenance during flood periods	All microbial pathogens	Ingestion	W1	Working in pairs	Observation and worker training	2	4	8	M	
		Injury to the body, including drowning	Falling into open drains	W1	Working in pairs	Observation and worker training	2	16	32	H	
T1: Sewer system	Ingestion of contaminated groundwater due to leakage from sewers and drains into shallow groundwater	All microbial pathogens	Ingestion	L1	Nil	n/a	2	4	8	M	No records of poor drinking-water quality exist for normal conditions. Contamination of drinking water has, however, been reported during flood periods.
T1: Sewer system	Ingestion of contaminated groundwater due to leakage from sewers and drains into shallow groundwater in floods	All microbial pathogens	Ingestion	L1	Nil	n/a	3	4	12	M	
T1: Sewer system	Mosquito breeding in stagnant water enhances transmission of malaria	Vector-related diseases	Mosquito bites	L1	Nil	n/a	4	4	16	H	*Plasmodium vivax* malaria (the only endemic *Plasmodium* species in Sanitola) does not result in fatal illness.

Newtown Table 3.3 Newtown's risk assessment table cont.

Sanitation step	Hazard identification				Existing control(s)		Risk assessment Allowing for the existing control L=Likelihood; S=Severity; R=Risk level				Comments justifying risk assessment or effectiveness of the control
	Hazardous event	Hazard	Exposure route	Exposure groups	Description of existing control	Validation of control	L	S	Score	R	
P2: Local use for irrigation and produce production in or from drains	Exposure to raw sewage in open drains during farming activities or playing	All microbial pathogens	Ingestion	F1	Nil	n/a	5	4	20	H	Farmers in direct contact with untreated sewage.
				F2	Nil	n/a	5	4	20	H	F2 plant and harvest water spinach and bamboos in the drains.
				L1	Nil	n/a	5	4	20	H	Children observed to play in open drains.
		Hookworm	Skin penetration	F1	Nil	n/a	4	4	16	H	Farmers are in direct contact with untreated sewage. Children are involved. Hookworm infection can cause health effects, particularly in younger age groups. While most will feel minor health effects, some may experience illness. Consequently, the moderate severity category was selected.
P2: Local use for irrigation and produce production in or from drains				F2	Nil	n/a	5	4	20	H	F2 plant and harvest water spinach and bamboos in the drains.
				L1	Nil	n/a	5	4	20	H	Children observed to play in open drains.
P2: Local use for irrigation and produce production in or from drains	Spray irrigation resulting in exposure to irrigation water	All microbial pathogens	Inhalation	F2	Low level irrigation		1	4	4	L	Irrigation is applied at ground level with hoses at base of trees.
P2: Local use for irrigation and produce production in or from drains	Consumption of contaminated produce	All microbial pathogens	Ingestion	C1	Post-harvest cooking of produce	Local practice observed	3	4	12	M	Produce is normally cooked before being eaten.
				C2	Low level irrigation and high crops		3	4	12	M	Produce is grown at high level (fruit tress) well above direct contact with sewage, but unhygienic handling of produce is possible.
T2: Vacuum tanker operation	Exposure to raw sewage during vacuum tanker operation	All microbial pathogens	Ingestion	W2	Gloves, boots and face mask		3	4	12	M	Handwashing and washing of equipment after emptying activities is not widely practiced.
T2: Vacuum tanker operation	Bad odours causes unease	Malodours	Inhalation	W2	Face masks		5	2	10	M	Face masks are only partly effective.
T2: Vacuum tanker operation	Falling into open pit	All microbial pathogens	Ingestion	W2	Nil		2	4	8	M	
		Injury to the body	Falling into pit	W2	Nil		2	8	16	H	

Newtown Table 3.3 Newtown's risk assessment table cont.

Sanitation step	Hazard identification				Existing control(s)		Risk assessment Allowing for the existing control L=Likelihood; S=Severity; R=Risk level				Comments justifying risk assessment or effectiveness of the control
	Hazardous event	Hazard	Exposure route	Exposure groups	Description of existing control	Validation of control	L	S	Score	R	
P3: WWTP operations (Waste Stabilization Ponds)	Exposure to raw sewage in treatment plant operation and maintenance causes illness	All microbial pathogens	Ingestion	W3	Gloves, boots and equipment used	Observations	3	4	12	M	Handwashing and washing of equipment after emptying activities is generally practiced.
P3: WWTP operations (Waste Stabilization Ponds)	Mosquito breeding in stagnant water of the plant enhances Transmission of malaria and filariasis	Vector-related diseases	Mosquito bites	W3	Occasional spraying	Staff reports	3	4	12	M	*Plasmodium vivax* malaria (the only endemic *Plasmodium* species in Sanitola) does not result in fatal illness.
				L3	Occasional spraying	Staff reports	3	4	12	M	
P3: WWTP operations (Waste Stabilization Ponds)	Bad odours causes unease	Malodours	Inhalation	W3	Face masks	Observation	5	2	10	M	Plant is overloaded and as a result there are high odours. Face masks are seldom worn. Long term exposure to malodours can cause headaches and unease.
P3: WWTP operations (Waste Stabilization Ponds)		All microbial pathogens	Ingestion	W3	Nil	Observation	2	4	8	M	It is unheard for someone to fall into the ponds.
	Falling into ponds	Injury to the body, including drowning	Falling into pond	L3	Site is fenced	Observation	1	16	16	H	
				W3	Nil	Observation	2	16	32	H	

Newtown Table 3.3 Newtown's risk assessment table cont.

Sanitation step	Hazard identification				Existing control(s)		Risk assessment Allowing for the existing control L=Likelihood; S=Severity; R=Risk level				Comments justifying risk assessment or effectiveness of the control
	Hazardous event	Hazard	Exposure route	Exposure groups	Description of existing control	Validation of control	L	S	Score	R	
P4: Farmer irrigation and produce production	Exposure to sewage in irrigation water or in-field farming practices causes illness	All microbial pathogens	Ingestion	F3	Treatment plant effluent only is used (not raw wastewater). Farmers and community members wearing footwear. Otherwise no control measure observed	Treatment plant process analysis and samples of effluent.	5	4	20	H	Log reduction of *E. Coli* of applied water is about 1.7. This compares with Guidelines of a 4 log reduction for safe use in labour intensive farms. Water quality confirmed during validation process.
				L2			5	4	20	H	
		Hookworm	Skin penetration	F3	Farmers wearing footwear	Observation	3	2	6	M	Adult hookworm infection usually results in minor health effects.
				L2	Nil		4	4	16	H	Children observed to play in the fields. Hookworm infection can cause health effects, particularly in younger age groups. While most will feel minor health effects, some may experience illness. Consequently, the moderate severity category was selected.
P4: Farmer irrigation and produce production	Spray irrigation resulting in exposure to irrigation water	All microbial pathogens	Inhalation	F3	Nil		4	4	16	H	Spray irrigation trial under way.
				L2	Nil		2	4	8	M	Possible side drift in strong winds.
P4: Farmer irrigation and produce production	Consumption of contaminated produce	All microbial pathogens	Ingestion	C3	Post-harvest washing is not rigorous	Observations	3	4	12	M	Some crops are eaten uncooked. Post-harvest washing is carried out, but not rigorously.
P6: Water intake for downstream community	Drinking water in Village A downstream is unsafe for consumption and use	All microbial pathogens	Ingestion	L4	Treatment plant and water system operating under a Water Safety Plan	WSP procedures	2	4	8	M	

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Newtown Table 3.3 Newtown's risk assessment table cont.

Sanitation step	Hazard identification				Existing control(s)		Risk assessment Allowing for the existing control L=Likelihood; S=Severity; R=Risk level				Comments justifying risk assessment or effectiveness of the control
	Hazardous event	Hazard	Exposure route	Exposure groups	Description of existing control	Validation of control	L	S	Score	R	
P7: Groundwater extraction by communities adjacent to F3 farmers	Ingestion of contaminated groundwater due to leakage from ponds in treatment plant	All microbial pathogens	Ingestion	L3	Nil		3	4	12	M	Likelihood ranked as 3 given uncertainty and lack of data. To be reviewed once more data is obtained.
P8: Landfill	Drinking water contaminated because leachate of sludge escapes	All microbial pathogens	Ingestion	L1 to L4	Controlled transfer to and dumping at landfill site, meets regulations and is downstream of water intake	Observations	1	2	2	L	It is assumed that water leached would be of very low concentration and is filtered by natural strata.

Based on the risk assessment table, a sample of Newtown's prioritized risks (for further action in Module 4 and Module 5) is presented below. Only the high risks are shown as none of the risks were classified as very high.

Newtown Table 3.4 Prioritized risks

Sanitation step	Hazardous events	Exposure group
Very high risk hazardous events		
T1: Sewer system	Falling into open drains in flood periods	L1
High Risk hazardous events		
T1: Sewer system	Exposure to raw sewage in open drains during maintenance activities	W1
	Exposure to raw sewage in open drains when playing	L1
	Falling into open drain resulting in injury	L1
	Exposure to raw sewage due to overflowing drains in flood periods	L1
	Falling into drains during maintenance in flood periods	W1
	Mosquito breeding in stagnant water enhances transmission of malaria	L1
P2: Local use for irrigation and produce production in or from drains	Exposure to raw sewage in open drains during farming activities or playing	F1 F2 L1
T2: Vacuum Tanker operation	Falling into open pit	W2
P3: WWTP Operations (Waste Stabilization Ponds)	Falling into ponds	W3 L3
P4: Farmer irrigation and produce production	Exposure to raw sewage in irrigation or in-field farming practices causes illness	F3 L2
	Spray irrigation resulting in exposure to irrigation water	F3

Module 4. Develop and implement an incremental improvement plan

Module 4.1 Consider options to control identified risks

Newtown Table 4.1 represents a sample of the table used to compare new control measures and improvement plan options in Newtown.

This table shows a comparison of options to reduce the risk with a special focus in Exposure Groups F3 and L2.

Newtown Table 4.1 Improvement plan options

Improvement plan options				
Possible control measures for farmers and their families	**Comments/discussion**	**Likely effectiveness of option in reduction of risk of the hazardous event**	**Reference/validation**	**Priority for improvement plan**
Improved treatment: Full treatment in upgraded Waste Stabilization Ponds to achieve < 1000 *E. Coli*/100 ml and < 1 egg/litre (including maturation pond)	This is an improvement of the existing control measure. Full treatment would be expensive, and seen as unlikely is short to medium term.	High effectiveness (> 4 log reduction).	2006 WHO Guidelines (Vol 2 page 81) and texts on Waste Stabilization Ponds.	Long term.
Partial treatment: Reinstate maturation pond as part of normal process train	This is an improvement of the existing control measure but to a lesser extent than full treatment. No substantial adjustment to existing ponds, just reinstatement of existing maturation pond. Will make substantial reduction to helminth eggs. A further 5 day detention will reduce egg count to 1 / litre. *E. coli* will reduce to $5.8x\ 10^3$ /100 ml. See Note 1.	High effectiveness for farmer protection. ***E. coli***: Total new log reduction of approx 3.3 (compared with existing of approx. 1.7 log reduction). **Helminth eggs**: will achieve about target of about 1 egg/litre.	Calculation on egg reduction in 2006 WHO Guidelines (Vol 2 page 85) and Waste Stabilization Ponds texts.	Short/medium term.
Crop restriction	Not relevant to farmer protection except when used in conjunction with localized irrigation.	Not applicable for farmer protection, but does provide high protection for consumers of the crops.	2006 WHO Guidelines (Vol 2 page 78).	Not relevant – not proposed for further consideration.
Improved spray irrigation techniques	Use low throw, micro sprinklers, part circle sprinklers.	Low to moderate effectiveness for farmer and local community – approximately, 0.5 log reduction.	2006 WHO Guidelines (Vol 2 page 64 and 77).	Immediate/short term

Improvement plan options				
Possible control measures for farmers and their families	**Comments/discussion**	**Likely effectiveness of option in reduction of risk of the hazardous event**	**Reference/validation**	**Priority for improvement plan**
Introduction of localized irrigation	For example: bubble, drip, trickle feed. Given low cost and high availability of water, not seen as economically viable. Expensive options, but do offer high protection to farmers.	High effectiveness (2-4 log reduction) depending on whether harvested portion of crop is touching the ground. If no crop restrictions, can offer only 2 log reduction.	2006 WHO Guidelines (Vol 2 page 77, 78 and Table 4.3).	Not proposed for further consideration
Farmer protective clothing	For example: boots/shoes, gloves. Needs highly motivated famers and high risk of non-compliance by farmers.	Not quantified but will have important positive effects.	2006 WHO Guidelines (Vol 2 page 79).	Immediate/short term
Farmer improved hand washing and hygiene	For example: improved access to good hand washing and washing/bathing facilities for farmers. Moderately expensive option, but does offer high protection to farmers.	Not quantified but will have important positive effects.	2006 WHO Guidelines (Vol 2 page 79).	Immediate/short term

Note: These comments are based on the specific case in Newtown only. The assumed reduction was calculated based on the flow, strength, current hydraulic detention times, pond depth etc. using standard wastewater treatment process formula and principles.

We were surprised to see how much improvement was possible by even simple measures.

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Module 4.2 Use selected options to develop an incremental improvement plan

We are looking forward to implementing these improvements. (Module 4.3).

Newtown Table 4.22 Samples of some improvement plan outlines

Sanitation step	Hazardous event	Improvement action(s)* (new/improved control measures)	Priority (high, medium, low)	Responsible agency/ person	Due	Status
T1: Sewer system	Falling into open drains during flood periods.	Programme in schools highlighting dangers of drains during flood periods. Accompanying children near drains during flood periods.	High	Newtown Education Dept.	Start of every monsoon season	Not shown here
P4: Farmer irrigation and produce production	Spray irrigation resulting in exposure to irrigation water.	Improved spray irrigation techniques – use low throw, micro sprinklers, part circle sprinklers.	High – immediate term implementation	Farmer cooperative	6 months from adoption of SSP. i.e. by (insert date)	
	Exposure to raw sewage in irrigation water or in-field farming practices causes illness.	Partial treatment: Reinstate maturation pond as part of normal process train.	High – immediate term implementation	Sewerage Board – Manager	9 months from adoption of SSP i.e. by (insert date)	
		Farmer protective clothing - for example: boots/shoes, gloves with associated farmer education program.	High – immediate term implementation	Farmer cooperative and Dept. of Health	3 months from adoption of SSP. i.e. by (insert date)	
		Farmer improved hand washing and hygiene Conduct education and behaviour change campaign with local community.	High – immediate implementation	Farmer cooperative and Dept. of Health	6 months from adoption of SSP. i.e. by (insert date)	

*Other SSP teams may also choose to add a cost column.
Note: This table gives examples only. Other example improvement plans are not shown due to space limitations.

Module 5. Monitor control measures and verify performance

Module 5.1 Define and implement operational monitoring

Tool 5.1 forced us to think carefully about which control measures would be most useful to monitor to ensure we kept our control measures operating as intended.

This table shows a sample only.

For each of these we developed detailed plans.

Newtown Operational monitoring overview plan

Sanitation step	Control measures to have a detailed operational monitoring plan
Waste generation	No control measure priorities in short term, but improved regulations and enforcement on industrial and health facility wastes discharges to sewer to be done as a lower priority to maintain current low risks related to chemicals etc.
Waste transport/conveyance	Education and promotion of safety along the open channels/drains and on safe irrigation practices by local community. Personal protective equipment (for vacuum truck and sewer network workers).
Waste treatment/processing	Improved treatment plant performance – linked to improvement plans to upgrade plant. Monitoring actions will include flow rate control, dissolved oxygen monitoring, effluent testing and sampling etc. Personal protective equipment (for vacuum truck and sewer network workers).
Waste use or disposal of by-product	Waste application timing and time to harvest. Personal protective equipment (for farm workers).
Consumption or use of the product	Education and promotion of safe food preparation.

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There are about 15 operational monitoring plans (developed in detail using Tool 5.2) but, due to space limitations, only one is shown (Newtown Table 5.2). For each operational monitoring plan, field-friendly log sheets were developed.

Newtown Table 5.2 Operational monitoring plan for personal protective equipment use by farmers

Operational monitoring plan for: Personal protective equipment use by farmers				
Operational limits (see note below)	**Operational monitoring of the control measure/control measure:**		**Corrective action when the operational limit is exceeded**	
80% of the farmers use standardized labour protection when exposed to wastewater	**What is monitored**	Frequency of labour protection used by the farmers	**What action is to be taken**	Identify why the farmers are not using protective equipment. Modify and improve information, education and communication programme.
	How it is monitored	Observation, survey		
	Where it is monitored	Newtown's farming area	**Who takes the action**	Farmers' Association, local health centre
	Who monitors it	Farmers' Association, local health centre	**When it is taken**	Commence investigations within one week
	When it is monitored	Once per week	**Who needs to be informed of the action**	Local office of Department of Agriculture

Note: If the monitoring is outside this limit(s), the control measure is deemed to be not functioning as intended.

Module 5.2 Verify system performance

Key verification included *E.coli* and helminth egg monitoring of the irrigation water.

Health records from a local health centre and a distant control health centre were collected and analysed every two years.

It was also decided to conduct an annual produce consumer perception survey.

In setting the verification we were mindful of the practical limitations of the Ministry of Health and Newtown municipality in testing but recognized that it was important that stakeholders obtained data on the effectiveness of the SSP interventions. It was decided that microbial testing of the crops was currently impractical, but that the Steering Committee should pursue this before the first review of the plan.

Module 5.3 Audit the system

It was decided to review auditing requirements in two years after some experience had been gained in operating the plan.

While recognized the value in auditing, we took this decision given our current lack of experience in even simple ad-hoc internal audits, but plan to increase our confidence and experience in this over the next two years.

Module 6. Develop supporting programmes and review plans

Module 6.1 Identify and implement supporting programmes and management procedures

Supporting programmes

- Health and Safety training programmes for staff (e.g. treatment plant operators and vacuum tanker operators). Annually and as part of induction programmes.
- Presentation of evidence and results to public and institutional stakeholders in the annual report, annual open day and annual steering committee meeting.
- Awareness raising and training for key exposure groups to improve compliance for control measures that require behaviour change.
- Routine maintenance programmes.
- Public awareness campaigns including training for staff on best practice in these campaigns.
- Training and education in efficient agricultural practices for water users.

Management procedures included

- A range of standard operating procedures – covering, for example:
  - worker safety (e.g. working beside open ponds, pump repair procedures, personal protective equipment use);
  - desludging and transport of septage;
  - waste stabilization pond desludging including proper on-site storage.
- Operation, maintenance and testing schedules.

These programs and procedures are, of course, specific for Newtown.

As we considered our needs we realized that while we have some reasonable programmes and procedures in our water supply system, we had considerable room for improvement in the sanitation sector. And, to meet our objectives (see Module 1.1), we had to include the agricultural practices and consumer health, as well as the traditional engineering aspects of sanitation. The tension was to ensure that the plan was able to be implemented within budget constraints yet meet our SSP objectives.

Module 6.2 Periodically review and update the SSP outputs

The first formal review of the plan is to take place in two years.

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ANNEX 1

Example control measures for biological hazards

The following pages outline tables of example control measures for use in SSP. Effectiveness of the control measures are rated as between VERY LOW – HIGH, depending on the treatment train and, where available, the microbial log reduction values.

A1-1 Wastewater treatment

Table A1-1 Control measures related to wastewater treatment

Alternative	Effectiveness/ log reduction	Remarks	Further reading
Waste stabilization ponds, aerated ponds, wastewater storage and reservoirs	HIGH 2–5 logs	Effectiveness depends on configuration and storage time, loading rates and retention times, hydraulic design details and sedimentation efficiency. Other associated issues to consider for risk management for workers and local community include: • mosquito vector breading potential; • *Schistosoma* spp. host snail potential and associated vegetation controls; • fencing; • possible exfiltration from ponds impacting on groundwater (e.g. use of pond liners with clay or other material).	Mahassen et al. (2008). Stenström et al. (2011), 68-70, 79, 129-130. WHO (2006) Vol. 2, 84-87.
Constructed wetlands	MEDIUM 1–3 logs	Effectiveness depends on design configuration (e.g. surface flow or subsurface flow wetlands), loadings and retention times. Other associated issues to consider for risk management for workers and local community include: • mosquito vector breading potential; • *Schistosoma* spp. host snail potential; • vegetation controls; • impact of wildlife excreta; • possible leakage from wetlands impacting on groundwater.	Stenström et al. (2011), 71-72, 79, 131-132. WHO (2006) Vol. 2, 87.
Biological chemical treatment	MEDIUM 1–3 logs	Control measures dependent of design and treatment configuration.	Stenström et al. (2011), 73-75. WHO (2006) Vol. 2, 82-84 & Table 5.3.
Advanced processes	HIGH 2–>6 logs		

A1-2 Wastewater in agriculture

In all agricultural wastewater applications some other associated issues to consider for risk management for workers, farmers and local community include:

- protection of wastewater treatment and storage facilities from animal and insect vectors;
- prevention of ponding of treated wastewater at application points which would promote vector breeding.

- Wastewater application rates should be managed to meet crop demands.

Table A1-2 Control measures related to wastewater in agriculture

Alternative	Effectiveness/ log reduction	Remarks	Further reading
Use of raw wastewater	VERY LOW to LOW	In respect of pathogen concentrations, raw wastewater should never be considered safe. Some other associated issues to consider for risk management for exposure groups include: • crop restrictions; • localized (e.g. drip) irrigation; • pre-harvest irrigation control (e.g. cessation of irrigation before harvest) to allow pathogen die-off before consumption (providing an interval between final irrigation and consumption); • harvest and post-harvest measures; • upgrade of treatment or new low-cost treatment.	WHO (2006) Vol. 2, 89-91.
Crop selection according to wastewater quality	HIGH	Effectiveness depend on: • use of crop (e.g. crops not intended for human consumption, such as cotton and oil crops, eliminates some potential risks; • the human access to cropping and irrigation areas (e.g. areas with more open access introduce more potential risks); • adherence to agreed crop restrictions.	WHO (2006) Vol. 1, 24. WHO (2006) Vol. 2, 76.
Wastewater application techniques: Subsurface irrigation	HIGH	This technique: • minimizes contact by farmers; • facilitates root uptake; • is very efficient with irrigation water use; • needs selection of non-clogging emitter and/or filtration to prevent clogging of emitters. Subsurface irrigation has a very large potential to minimize human contact and reduce water losses in water scarce areas. However surface entry and ponding (e.g. as a result of pipe blockages or breaks) must be controlled and managed. If surface entry occurs the reduction in human health risks potentially achieved are diminished.	WHO (2006) Vol. 1, 26. WHO (2006) Vol. 2, 76.

Alternative	Effectiveness/ log reduction	Remarks	Further reading
Wastewater application techniques: Use localized drip irrigation (high growing crops) – e.g. bubbler irrigation	HIGH 4 log	This technique: • needs to consider minimizing clogging of drip holes; • needs to control and minimize temporary ground storage of harvested crops to avoid possible crop contamination; • needs to reduce and manage surface ponding (see remarks under “Subsurface irrigation”); • has improved efficiency and effectiveness with mulch-bed which limits and controls surface entry. Produce stored on the ground can be contaminated to such an extent that the positive impacts of other barriers are negated.	Stenström et al. (2011), 93. WHO (2006) Vol. 1, 26.
Wastewater application techniques: Use localized drip irrigation (low growing crops)	MEDIUM 2 log	Effectiveness of technique in reducing risk varies according to crop type (e.g. root or leafy vegetable, eaten raw or cooked), and farming technique (degree of mechanization). This technique: • is improved with mulch-bed which limits and controls surface entry; • minimizes clogging of drip holes; • needs to reduce and manage surface ponding (see remarks under “Subsurface irrigation”); • needs to limit direct crop contact to irrigation point; • needs to control and minimize temporary ground storage of harvested crops to avoid possible crop contamination. Produce stored on the ground can be contaminated to such an extent that the positive impacts of other barriers are negated.	Stenström et al. (2011), 93. WHO (2006) Vol. 1, 26.
Wastewater application techniques: Furrow irrigation	LOW–MEDIUM	Effectiveness of technique in reducing risks varies according to crop type (e.g. root or leafy vegetable, eaten raw or cooked), and farming technique (degree of mechanization). Some other associated issues to consider for risk management for exposure groups include: • control of irrigation load practices to minimize soil wash and drainage to receiving surface waters; • control withholding time between last irrigation and harvest; • technique is subject to interference during rain. Care should be exercised to: • prevent ponding ; • control temporary ground storage of harvested crops. Produce stored on the ground can be contaminated to such an extent that the positive impacts of other barriers are negated	WHO (2006) Vol. 1, 23.
Wastewater application techniques: Spray irrigation (high pressure)	LOW–MEDIUM	Effectiveness of technique in reducing risk varies according to: • crop type (e.g. root or leafy vegetable, eaten raw or cooked); • location of spray irrigation in relation to local communities and farmers; • quality/pre-treatment of irrigation water. Care should be exercised to: • provide a spray buffer zone of 50–100 m from local communities, this can provide a 1 log reduction; • control spray drift (e.g.: prohibit spraying on days where wind speed and direction exceeds agreed limits); • control withholding time between last irrigation and harvest; • control temporary ground storage of harvested crops; • control loading rates and fertilization practices to minimize runoff to surface waters. Produce stored on the ground can be contaminated to such an extent that the positive impacts of other barriers are negated.	Stenström et al. (2011), 91-93. WHO (2006) Vol. 2, 64.

Alternative	Effectiveness/ log reduction	Remarks	Further reading
Wastewater application techniques: Spray irrigation (low pressure)	LOW–MEDIUM	Effectiveness of technique in reducing risk varies according to • crop type (e.g. root or leafy vegetable, eaten raw or cooked); • location of spray irrigation in relation to surrounding local communities and farmers; • quality/pre-treatment of irrigation water. Care should be exercised to: • control withholding time between last irrigation and harvest; • control temporary ground storage of harvested crops; • control fertilization practices; • deposition load per area.	Stenström et al. (2011), 91-93. WHO (2006) Vol. 2, 64. Amoah et al. (2011).
Wastewater application techniques: Ponds at farm site and watering cans (vegetables and root crops)	LOW	Effectiveness of technique in reducing risk varies according to • the quality/pre-treatment of irrigation water; • the mode of application and the exposure of farmers to the irrigation water; • the variability of application practices by different farmers; • the controlled withholding time between last irrigation and harvest. Care should be exercised to: • control temporary ground storage of harvested crops; • control loading rates and fertilization practices to minimize runoff to surface waters; Ponds at farm site have the potential for 1–1.5 log reduction of faecal coliforms. Local sand filtration has potential for 2 log reduction of faecal coliforms; 0.5–1.5 log reduction of *Ascaris* spp. eggs.	Amoah et al. (2011).
Pathogen die-off period of 1 week: Withholding wastewater application prior to harvesting	MEDIUM to HIGH	Actual log reductions are dependent on crop type and temperature and are site specific. Refer to Example 3.3 for more comments.	Stenström et al. (2011), 93. WHO (2006) Vol. 1, 32.
Crop storage prior to sale	MEDIUM	Effectiveness of technique in reducing risk varies according to: • storage conditions (e.g. additional contamination during storage and climatic conditions); • vermin access; • storage time. If combined with pathogen die-off period of 1 week – HIGH	
Additional handling safety	Important but not quantified	See Section A1-7 below. Risk reduction has not been quantified but is expected to have important positive effects.	WHO (2006) Vol. 2, Chapter 5.5.
Post-harvest exposure control measures	MEDIUM to HIGH 2–7	See Section A1-7 below. Includes extended storage, produce washing, disinfection peeling and cooking.	WHO (2006) Vol. 2, Chapter 5.4.

A1-3 Wastewater in aquaculture

Table A1-3 Control measures related to wastewater use in aquaculture

Alternative	Effectiveness	Remarks	Further reading
Pond water quality: $<10^3$ *E. coli* per 100 ml <1 helminth egg per litre	HIGH	• This would generally protect workers and consumers and no further control measures should be needed if wastewater is treated to this level. • Provide physical, chemical or biological control of host snail populations where *Schistosoma* spp. is endemic. • Consider mosquito vectors and measures to reduce vector breeding habitats. • Refer to WHO (2006) Vol. 3, 40 for notes on testing for viable trematode eggs.	WHO (2006) Vol. 3, 39-45.
Pond water quality: $<10^4$ *E. coli* per 100 ml <1 helminth egg per litre	MEDIUM to HIGH	• This would normally protect product consumers, however, additional worker and farmer control measures are required. • Provide physical, chemical or biological control of host snail populations where *Schistosoma* spp. is endemic. • Consider mosquito vectors and measures to reduce vector breeding habitats. • As a general rule, testing for viable trematode eggs in wastewater, excreta or pond water should be done at the system validation stage. If the plant and fish species raised in the local area are always eaten after thorough cooking, testing for viable trematode eggs will not be necessary. • Refer to WHO (2006) Vol. 3, 40 for notes on testing for viable trematode eggs.	A1-7. WHO (2006) Vol. 3, 39-45.
Raw or partially treated wastewater	MEDIUM (if control measures and enforcement in place, otherwise LOW)	• Produce should be restricted to fish species that are only eaten cooked. • Require processing or fish products prior to sale. • Refer to workers and farmers control measures in Section A1–7 – below. • Provide physical, chemical or biological control of host snail populations where *Schistosoma* spp. is endemic. • Consider mosquito vectors and measures to reduce vector breeding habitats. • Limit access to waste-fed aquaculture facilities. • Refer to WHO (2006) Vol. 3, 40 for notes on testing for viable trematode eggs.	WHO (2006) Vol. 3, 21, 41 & 47-68.
Produce restriction	LOW–HIGH	• Restrict produce to plants and fish which are eaten after cooking. • Ensure extra care for trematode infections in fingerling production.	WHO (2006) Vol. 3, 55.
Withholding period between waste application and harvest	MEDIUM	• Risk effectiveness is time dependent, and reduction is related to facultative ponds or maturation ponds functionality. • For optimum pathogen die-off prior to fish or plant harvest, a batch-fed process (i.e. all of the wastewater enters the treatment system at one time, and no new wastewater is added until the crop is harvested) could be used. It should be noted, though, that in urban areas, larger aquatic ponds will often be receiving untreated wastewater and latrine wastes from surrounding households on a continuous basis.	WHO (2006) Vol. 3, 57.
Depuration (before marketing, holding fish in clean water to reduce contamination)	MEDIUM	• Time dependent, 2–3 weeks recommended • Will not affect trematode concentration.	WHO (2006) Vol. 3, 57.

Alternative	Effectiveness	Remarks	Further reading
Food handling and preparation	MEDIUM	• Prevent fish flesh contamination. • Fish gut should be removed prior to handling the fish flesh. • Ensure clean knives and cutting boards are used.	WHO (2006) Vol. 3, 58.
Produce washing / disinfection	MEDIUM	• This relates to aquatic plants.	WHO (2006) Vol. 3, 58.
Cooking	HIGH	• Relates to all produce. • Contamination during storage after cooking may occur.	WHO (2006) Vol. 3, 58.
Health protection measures against trematodes	LOW–HIGH	• For a summary, see WHO (2006) Vol. 3, Table 5.4.	WHO (2006) Vol. 3, 63-68.

A1-4 Excreta use

Table A1-4 Control measures related to excreta use

Option	Alternative	Effectiveness/ log reduction	Remarks	Further reading
Excreta treatment: Primary (on-site)				
Excreta containment and storage	Single pit latrines	LOW to MEDIUM	• Pathogen die-off occurs with time. Risk relates to emptying practices. On-site contamination relates to siting, soil and hydrological conditions. • Unlined (or no liner on base) pit at least 2–3 m above the water table to prevent groundwater contamination and an adequate hydrological horizontal distance. • Adequate pit ventilation appropriate to toilet type. Smell may discourage use and wetness enhance fly breeding. • If urine diversion is applied the technical diversion functions should be ensured.	Stenström et al. (2011), 14, 28-29, 32. WHO (2006) Vol. 4, 80, 83.
Excreta containment and storage	Double alternating pit latrines	MEDIUM to HIGH	• Duel pits on toilets allow extended storage without fresh additions (design for >1.5–2 years storage). • Pit alternation should be ensured. • Extended storage to protect waste handlers. • Unlined (or no liner on base) pit at least 2 m above the water table to prevent groundwater contamination. • Adequate pit ventilation appropriate to toilet type. Smell may discourage use and wetness enhance fly breeding. • Observe handling of water for anal cleansing. • HIGH refers to: o 1.5–2 years of storage at 2–20°C where helminth infections are prevalent, or o at least 1 year storage at >20°C, or o storage of at least 6 month of pH is adjusted to above 9 (e.g. with lime or ash).	Stenström et al. (2011), 34-36, 87,96. WHO (2006) Vol. 4, 69, 80, 82-83.
Excreta containment and storage	Double dehydration vaults	MEDIUM to HIGH	Effectiveness: potentially high for viruses and bacteria in dehydration vaults and substantial reductions of helminth eggs. Refer to further reading for more complete explanations and research findings. • Dual pits on toilets allow extended storage without fresh additions • Extended storage provides protection to workers • Temperature and pH dependent • Adequate pit ventilation appropriate to toilet type • HIGH refers to: o 1.5–2 years of storage at 2–20°C where helminth infections are prevalent, or o at least 1 year storage at >20°C, or o storage of at least 6 month of pH is adjusted to above 9 (e.g. with lime or ash).	Stenström et al. (2011), 87. WHO (2006) Vol. 4, 69, 82-83.

Option	Alternative	Effectiveness/ log reduction	Remarks	Further reading
Excreta containment and storage	Aqua privy / composting latrines / septic tanks	LOW to HIGH	• Unlined (or no liner on base) pit should be at least 2 m above the water table to minimize groundwater contamination. • Adequate ventilation appropriate to toilet type. Smell may discourage use and wetness enhance fly or mosquito breeding. • Water availability may affect suitability (e.g. if water supply is limited, operation may be affected and there may be unhygienic conditions in the toilet). • Prevent blockages to minimize exposure to maintenance workers during cleaning operations. For example, pour flush latrines are not suitable if it is common practice to use bulky materials for anal cleansing. Maintenance workers should wear the necessary protective clothes (e.g. gloves). • If the moisture content in composting chambers is too high, this gives anaerobic conditions and if it is too low, this will slow down the biological degradation. • The pathogen removal in septic tanks is poor, and bacteria and viruses remain present in both the liquid and the solid phases. The removal of helminth eggs can be expected to be <0.5 log.	Stenström et al. (2011), 19-20, 38-39, 43-44, 96. WHO (2006) Vol. 4, 80-88.
Excreta containment and storage	Biogas reactors	MEDIUM to HIGH	• Efficiency relates to retention time and if the process is mesophilic or thermophilic o thermophilic (50–60°C), reduction within days 1.5–2; o mesophilic (30–38°C), reduction within weeks to months. For example, more than 3 log units of *Cryptosporidium* oocysts were inactivated in an anaerobic digester after 10 days at 37°C, 4 days at 47°C, and 2 days at 55°C. The corresponding time for *Ascaris* egg inactivation was less than 75 per cent after 10 days (37°C), 95 per cent in 2 days (47°C) and more than 3 logs in 1 hour (55°C). Thermophilic temperature conditions are rarely achieved in biogas reactors without additional heating.	Kato et al. (2003). Stenström et al. (2011), 47-48
Excreta conveyance				
	Human-powered emptying and transport	HIGH to MEDIUM	• Transport of treated rather than fresh waste. • Refer to workers and local community control measures in Section A1-7 – below.	Stenström et al. (2011), 57. WHO (2006) Vol. 4, 89.
	Motorized emptying (e.g. faecal sludge reduction by suction pump and transport)	Varies depending on exposure group and handling practice	• Transport of treated rather than fresh waste. • Refer to workers and local community control measures in Section A1-7 – below.	WHO (2006) Vol. 4, 89. Stenström et al. (2011), 59.

Option	Alternative	Effectiveness/ log reduction	Remarks	Further reading
Excreta treatment: Secondary				
	Full incineration (<10% carbon in ash)	HIGH	• Temperature to ensure total reduction of pathogens.	WHO (2006) Vol. 4, 68.
	Composting for at least 1 week if compost temperature of >50°C can be maintained	MEDIUM to HIGH	• HIGH if temperature can be ensured for all material; MEDIUM if not totally ensured. • For mesophilic composting, validation and verification monitoring applies. • For compost <50°C refer to storage periods for excreta (above). • *Ascaris* spp. >1.5–2 log reduction (thermophilic co-composting).	Kone et al. (2007). Stenström et al. (2011), 77. WHO (2006) Vol. 4, 68.
Secondary storage	Just storage		• Time/ambient temperature as for primary treatment process apply.	
Secondary storage	Alkaline treatment / storage	MEDIUM to HIGH	• pH >9 for >6 months (temp >35°C; moisture <25%). • Elimination time prolonged at lower pH or wetter material. • Time substantially shorter at pH 11 (e.g. lime, treatment).	WHO (2006) Vol. 4, 68.
Secondary storage	Drying beds and UV irradiation	MEDIUM to HIGH	• Helminth eggs, 3 log reduction (1 month). • Bacteria, 2.5–6 log reduction (4 months storage).	Kengne et al. (2009). Nielsen (2007). Stenström et al. (2011), 77,137.
Excreta handling and general considerations				
General			• Refer to workers control measures in Section A1-7 – below. • No further control measures should be needed if excreta is treated to <1 helminth egg per g total solids. • Containment of faecal sludge/biosolids during any storage to prevent runoff to local waterways. • Consider vermin/vector attraction.	Stenström et al. (2011), 99. WHO (2006) Vol. 4, 66.
Excreta use in agriculture Additional controls for excreta treated/not treated to <1 helminth egg per g of total solids				
Application at agricultural land	Full mixing of treated excreta with the soil	NON-QUANTIFYABLE (reduce contact)	• This use also benefits plant nutrient uptake. • Good personal hygiene during application should be followed.	Stenström et al. (2011), 87, 97. WHO (2006) Vol. 4, 78.
Application at agricultural land	Application at the time of sowing/planting	MEDIUM to HIGH	• Effectiveness related to die-off/withholding time between application and harvest.	

Option	Alternative	Effectiveness/ log reduction	Remarks	Further reading
Crop restrictions	Restrict treated excreta application to non-food crops or crops cooked or processed before consumption	HIGH	• This technique limits exposure to farmers contact during application, handling and harvest • Farmers should use good personal hygiene during application.	Stenström et al. (2011), 87. WHO (2006) Vol. 4, 77.
Enforce pathogen die-off for 1 month	Withholding waste application prior to harvesting	MEDIUM to HIGH	• Refer to workers and local community control measures in Section A1-7 – below. • May be combined with crop storage prior to sale for defined periods (LOW–MEDIUM) or a combination totalling 1 month.	USEPA (1992). WHO (2006) Vol. 4, 78.
Post-harvest exposure control measures	Washing with or without disinfectants (e.g. peeling, cooking)	MEDIUM to HIGH	• These are consumer protection measures. • Control measures are difficult to verify. • 1–7 log risk reduction possible depending on the measure.	WHO (2006) Vol. 4, 78-79.
Excreta use in aquaculture				
Excreta storage prior to pond addition		MEDIUM to HIGH	• Time dependent effect. • Storage times are counted only after the last addition of fresh faeces (i.e. as a batch operation). • Storage for 4 weeks reduces risks for trematodes substantially, storage for 10 weeks needed for *Fasciola* spp. • Reduction of pathogenic bacteria and viruses will occur.	WHO (2006) Vol. 3, 50.
Excreta pre-treated in biogas fermentation		LOW to MEDIUM	• Depends on treatment time and temperature. • Combination with other protection measures is recommended.	WHO (2006) Vol. 3, 51.

A1-5 Urine use

Table A1-5 Control measures related to urine use

Option	Alternative	Effectiveness/ log reduction	Remarks	Further reading
Urine treatment				
Urine storage	Urine clearly contaminated with faeces	NOT APPLICABLE	• The mixture should be treated / handled according to controls for wastewater (see Table A1-1).	
Urine storage	Storage of urine in sealed containers to prevent human or animal contact	LOW to HIGH	• Observe if faecal cross-contamination may occur. • Microbial reduction is time dependent. Time for 90% reduction in initial concentration (T90), Gram negative bacteria <5 days, *Cryptosporidium* 1 month, viruses approximately 1 to 2 months. • Reduce nitrogen losses. • Reduce human contact. • Reduce odour.	Stenström et al. (2011), 40-41. WHO (2006) Vol. 4, 70-71.
Urine storage	No dilution of urine to maximize pathogen die-off	NOT APPLICABLE	• Undiluted urine gives a pH of approx. 8.8 which enhance bacterial die-off. • Mosquito breeding may occur in diluted urine, but not in undiluted urine. • Inactivation of *Schistosoma haematobium* where applicable.	WHO (2006) Vol. 4, 70-71.
No urine storage prior to application	Applied at one family systems – fertilization of family plot	NOT APPLICABLE	• For an individual one-family system and when the urine is used solely for fertilization on individual plots, no storage is needed. • The likelihood of transmission between family members is much higher through person-to-person transmission than through the fertilization-crop cycle.	WHO (2006) Vol. 4, 70.
Urine storage prior to application	For crops consumed raw	HIGH	• Storage for at least 6 months at >20°C combined with a 1 month withholding period (no further control measures should be needed if waste is treated to this level).	Stenström et al. (2011), 85. WHO (2006) Vol. 4, 70.
Urine storage prior to application	For processed food and fodder crops	MEDIUM to HIGH	• Storage for at least 1 month at >20°C or at least 6 months at 4°C.	Stenström et al. (2011), 85.
Urine use in agriculture				
Urine storage prior to application	Mixing stored urine with the soil or applying it close to the ground	NON-QUANTIFYABLE (reduce contact)	• Benefit plant nutrient uptake. • Personal hygiene during application.	WHO (2006) Vol. 4, 66, 70.
Urine storage prior to application	Cessation of urine application one month prior to harvest for crops consumed raw	HIGH	• Risk level below 10^{-6} DALY if combined with storage recommendations.	WHO (2006) Vol. 4, 70.

A1-6 Greywater use

Table A1-6 Control measures related to greywater use

Option	Alternative	Effectiveness/ log reduction	Remarks	Further reading
Greywater treatment				
General aspects	See WHO Vol IV Fig 5.11	MEDIUM to HIGH 1–4 logs	• Faecal load usually 3–5 logs lower than wastewater. • Easily degradable organic matter may result in regrowth of indicator bacteria. • Treatment methods for wastewater generally applicable for greywater. • Protect greywater treatment and storage facilities from animal and insect vectors. • Subsurface irrigation is recommend when greywater is heavily contaminated, vector breeding is likely or pond treatment is not possible.	WHO (2006) Vol. 4, 66, 77, 93-99 & Fig 5.
Greywater use in agriculture				
Greywater irrigation	Wastewater treatment methods apply	LOW–HIGH	• Crop restrictions are not normally necessary if faecal contamination is low and treatment is applied. • Application of greywater using close-to-the-ground methods are recommended. • Prevent ponding of greywater at application points that could promote vector breeding sites.	WHO (2006) Vol. 4, 78.

A1-7 Examples of control measures to protect workers, farmers, local community and consumers

Table A1-7 Control measures related to protection of workers, farmers, local community and consumers
(**Note**: some of these controls have also been noted in Tables A1-1 to A1-6)

Workers (W)

- Personal protective equipment (e.g. gloves, masks, enclosed waterproof footwear).
- Tools that assist in limiting exposure (e.g. vacuum tankers).
- Training on safe handling.
- Optimized treatment prior to handling.
- Design of the facility to optimize safe waste removal.
- Avoiding and containing spills.
- Dedicated tools for waste handling (or proper disinfection and cleaning between uses).
- Minimal manual handling of waste that has not been pre-treated.
- Washing body with soap and safe water after exposure to wastewater where schistosomiasis is endemic.
- Use of vector barriers such as repellents and prophylaxis, chemoprophylaxis and immunization.
- Immunization for typhoid.
- Treatment for helminth infections 2–3 times yearly.
- Treatment for schistosomiasis where it is endemic.
- Treatment of skin abrasions and cuts.

Note: General handling precautions are defined as additional measures and not a proper barriers.

Farmers (F)

- Personal protective equipment (e.g. gloves, masks, enclosed waterproof footwear).
- Subsurface irrigation.
- Use close-to-the-ground application techniques.
- Tools that assist in limiting exposure (e.g. hoses vs watering cans, long handle equipment vs trowels).
- Restricting workers access to field during mechanical application of wastewater.
- Access to safe drinking-water and toilets in the workplace.
- Personal hygiene and hygiene promotion training for workers.
- Washing body with soap and safe water after exposure to wastewater where schistosomiasis is endemic.
- Use of vector barriers such as repellents and prophylaxis, chemprophylaxis and immunization.
- Immunization for typhoid.
- Treatment for helminth infections 2–3 times yearly.
- Treatment for schistosomiasis where it is endemic.
- Treatment of skin abrasions and cuts.

Note: General handling precautions are defined as additional measures and not a proper barriers.

Consumers (C)

- A pathogen die-off period of 1 month either by:
  - withholding waste application prior to harvesting,
  - crop storage prior to sale, or
  - a combination of the above totalling 1 month.

Post-harvest exposure control measures:

- Produce washing with water.
- For fish, adoption of processing measures that do not cross contaminate between the guts and flesh.
- Produce disinfection.
- Produce peeling (fruits and root crops).
- Produce cooking.
- Good personal hygiene – especially handwashing with soap prior to food preparation and prior to eating.
- Market hygiene.
- Education of vendors.
- Provide safe water in markets.
- Mass drug administration or vaccination.

Local community (L)

- Fencing of the waste treatment facility to prevent children and animals entering.
- Warning signs (especially for unfenced ponds and fields).
- Education campaigns for local residents.
- Access to safe drinking-water and sanitation for local communities.
- Reduce opportunities for vector breeding.
- Where wastewater is applied with spray irrigation a buffer zone of 50–100 metres from residents should be maintained.
- Restricted public access to fields or waste-fed aquaculture facilities
- Prohibit recreation activities and treatment ponds.
- Use of vector barriers such as repellents and prophylactics.
- Treatment for helminth infections 2–3times yearly for vulnerable.

Sources: Stenström et al. (2011), 74-78, 93, 100. WHO (2006) Vol. 2, 79-80; Vol. 3, 21, 43-45, 47-68; Vol. 4 74-78.

ANNEX 2

Summary of microbial health risks associated with the use of wastewater for irrigation

Table A2-1 Summary of microbial health risks associated with the use of wastewater for irrigation

Group exposed	Bacterial/virus infections	Protozoan infections	Helminth infections
Farm workers and their families	Increased risk of diarrhoeal disease in children with wastewater contact, if water quality exceeds 10^4 faecal coliforms /100 ml; elevated risk of *Salmonella* infection in children exposed to untreated wastewater; elevated sero-response to norovirus in adults exposed to partially treated wastewater.	Risk of *Giardia intestinalis* infection significant for contact with both untreated and treated wastewater; One study in Pakistan has estimated a threefold increase in risk of *Giardia* infection for farmers using raw wastewater as compared to fresh water; increased risk of amoebiasis observed with contact with untreated wastewater.	Significant risk of helminth infection of adults and children for untreated wastewater; increased risk of hookworm infections for workers without shoes; risk remains, for children, but not for adults, even when wastewater is treated to < 1 helminth egg/l.
Populations living within or near wastewater irrigation sites	Poor water quality sprinkler irrigation with (10^6–10^8 total coliforms /100 ml) and high aerosol exposure associated with increased infections; use of partially treated water (10^4–10^5 faecal coliforms /100 ml or less) in sprinkler irrigation not associated with increased viral infection rates.	No data on transmission of protozoan infections during sprinkler irrigation with wastewater.	Transmission of helminth infection not studied for sprinkler irrigation, but same as above for flood or furrow irrigation with heavy contact.
Consumers of wastewater irrigated produce	Cholera, typhoid and shigellosis outbreaks reported from the use of untreated wastewater, sero-positive responses for *Helicobacter pylori* (untreated); increase in non-specific diarrhoea when water quality exceeds 10^{-4} faecal coliform/100 ml.	Evidence of parasitic protozoa found on wastewater irrigated vegetable surfaces but no direct evidence of disease transmission.	Significant risk of helminth infection for both adults and children with untreated wastewater.

Source: Stenström et al. 2011: 92. Refer to Stenström et al. 2011 page 91–92 for additional comments related to the health risk evidence.

ANNEX 3

Wastewater chemicals in agriculture and aquaculture

Wastewater chemicals in agriculture

Often the limits of concentrations of many chemicals in wastewater will be determined by crop requirements not by human health concerns. The concentrations at which chemicals in wastewater become toxic to plants or unsuitable for agricultural production are typically lower than concentrations that would be of concern for human health.

Chemical concentrations in irrigation water are used to determine suitably of wastewater for plant growth. The physicochemical quality of treated wastewaters used for crop irrigation should comply with the guideline values set by the Food and Agricultural organisation summarized in Annex 1 of 2006 WHO Guidelines Volume 2.

Chemical concentrations in soil are used to determine suitability for human health, as human exposure to chemicals is assessed through food chain transfer from wastewater to the soil, uptake to plant and consumption by humans. The concentrations in Table A3-1 define safe concentrations in the soil above which the transfer of pollutants to people via the food-chain may occur. During waster irrigation, the concentration of inorganic elements in soils will slowly rise with successive applications. However, for many of the organic pollutants, the likelihood is small that they will accumulate in the soil to their computed threshold concentrations because their typical concentrations in wastewaters are very low.

Table A3-1 Maximum tolerable soil concentrations of various toxic chemicals based on human health protection

Elements	Soil concentration (mg/kg)	Organic compounds	Soil concentration (mg/kg)	Organic compounds	Soil concentration (mg/kg)
Antimony	36	Aldrin	0.48	PCBs	0.89
Arsenic	8	Benzene	0.14	Pentachlorophenol	14
Barium[a]	302	Chlordane	3	Phthalate	13 733
Beryllium[a]	0.2	Chlorobenzene	211	Pyrene	41
Boron[a]	1.7	Chloroform	0.47	Styrene	0.68
Cadmium	4	2,4-D	0.25	2,4,5-T	3.82
Fluorine	635	DDT	1.54	Tetrachloroethane	1.25
Lead	84	Dichlorobenzene	15	Tetrachloroethylene	0.54
Mercury	7	Dieldrin	0.17	Toluene	12
Molybdenum[a]	0.6	Dioxins	0.00012	Toxaphene	0.0013
Nickel	107	Heptachlor	0.18	Trichloroethane	0.68
Selenium	6	Hexachlorobenzene	1.40		
Silver	3	Lindane	12		
Thallium[a]	0.3	Methoxychlor	4.27		
Vanadium[a]	47	PAHs (as benzo[a]pyrene)	16		

[a] The computed numerical limits for these elements are within the ranges that are typical for soils.

Source: 2006 WHO Guidelines Vol 2, pp 72.

Wastewater chemicals in aquaculture

Specific information on chemicals in relation to waste-fed aquaculture is presented in section 3.3 of 2006 WHO Guidelines Vol 3.

The Codex Alimentarius Commission (http://www.codexalimentarius.org/) establishes tolerances for specific chemicals in food products. Table A3-2 gives the standards noted in the 2006 WHO guidelines. Users should also check source references for potential updates to standards and limits over time and to any national standards.

Table A3-2 Standards for chemical concentrations in fish and vegetables as reported in 2006 WHO Guidelines

Chemical	Standard for fish and fish products (mg/kg)	Source of standard	Standard for vegetables (mg/kg)	Source of standard
Heavy metals				
Arsenic	NS		0.2	Codex
Cadmium	0.05–1.0	EC	0.2	Codex
Lead	0.3	Codex	0.1 0.1 (fruiting vegetables) 0.3 (leafy vegetables)	Codex
Methyl mercury	0.5-1.0	Codex	NS	
Organics				
Dioxins	0.000 004	EC	NS	
DDT, TDE	5.0	USFDA	NS	
PCBs	2.0	USFDA	NS	

Source: 2006 WHO Guidelines Vol 3, pp 43.

NS: no standard.

To check for periodic updates to values refer to:
Codex Alimentarius International Food Standards: www.codexalimentarius.org/
EC, European Commission: www.ec.europa.eu/food/food/chemicalsafety/contaminants/index_en.htm
USFDA, United States Food and Drug Administration: www.fda.gov/Food/FoodborneIllnessContaminants/default.htm

The tolerable concentrations of toxic chemicals in fish and vegetables could be used in some verification programs. Verification monitoring of chemical concentrations in waste-fed aquacultural products should be conducted at six-month intervals at the point of sale. Comparisons between waste-fed fish or plants and non-waste-fed products sold in the market may provide insight into what specific contaminants are related to the use of wastewater or excreta. Contaminants that are at elevated concentrations can be singled out for more routine monitoring as necessary.

Notes

Notes

The SSP manual is targeted at a variety of users at different levels

Health authorities and regulators (e.g. as a tool to introduce risk based approaches in the sanitation sector, and verify their effectiveness).

Local authorities (e.g. as a tool for planning investment in sanitation especially in low resource settings).

Wastewater utility managers (e.g. to assist in managing effluent quality and safeguarding public and occupational health from source to end use or disposal).

Sanitation enterprises and farmers ater utility managers (e.g. to complement quality assurances procedures for safety of end products, workers, local communities, and consumers or users of the product).

Community based organizations, farmers associations and NGOs (e.g. to support community based water and sanitation programs in safe use of human wastes).

This Sanitation Safety Planning Manual provides practical step-by-step guidance to assist in the implementation of the 2006 WHO Guidelines for Safe Use of Wastewater Excreta, and Greywater in Agriculture and Aquaculture. The approach and tools may also be applied to all sanitary systems to ensure the system is managed to meet health objectives.

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