STANDARD OPERATING PROCEDURE FOR THE PHYSICOCHEMICAL TREATMENT OF CTC WASTEWATERS

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Preamble

When cholera strikes in a low-income country, the rapid construction and successful operation of specialist cholera treatment centres (CTC) by medical NGOs can significantly reduce the mortality rate. Such has been the case in Haiti. Since cholera struck the eastern part of the island of Hispaniola in October 2010, in the aftermath of a devastating earthquake ten months earlier, *Médecins Sans Frontières* has operated five different CTCs and treated, as of October 2011, more than 160,000 cholera patients.

Although a CTC provides patients with twenty-four hour access to specialist medical care and potentially limits cholera transmission within at-risk communities, it also necessarily results in the production of a large volume of pathogen-laden human faecal waste (containing as many as 10^8 *Vibrio cholerae* organisms per 100 ml). This waste clearly has the potential to contaminate water supplies and to further the transmission of the disease.

Options for wastewater management chosen by other governmental and nongovernmental institutions in Port-au-Prince were:

1. To transport untreated waste by tanker for disposal at a centralised facility at the city landfill site (Truitier):

2. To super-chlorinate waste streams prior to disposal at the Truitier landfill site, without further treatment.

MSF-OCA decided that using the Truitier landfill site presented obvious risks to human health and that this was therefore not compatible with MSF core values. Truitier, which was the only centralised waste and wastewater disposal option available in the city, is situated close to the impoverished and densely populated community of Cité Soleil. The entire area is located on the

Plaine Cul-de-Sac aquifer, which traditionally provides fresh water for the city of Port-au-Prince. Using this disposal option for CTC wastes would pose an unacceptable risk of disease transmission among the city's most vulnerable communities.

Therefore, MSF decided to look for an alternative approach.

From December 2010 to April 2011 (at Delmas 33 CTC), and from August to September 2011 (at the 'Tennis Court' CTC), in Port au Prince Haiti, MSF-OCA experimented with different methods to treat CTC wastewaters.

The main issues that suggested the need for an **onsite** wastewater treatment solution were:

- A high water table;
- limited space; and
- absence of a sewerage system and centralised wastewater treatment facilities in Port-au-Prince

Clearly the conventional MSF method of using on-site treatment using pit latrines followed by well-managed infiltration pits was not possible in this environment, and off-site disposal would involve hazardous tanker operation and a safe final disposal option, which were not available in Port-au-Prince.

While alternative treatment and disposal options were investigated, above-ground latrines were constructed and liquid waste was temporarily collected in plastic “tough tanks” of various sizes (0.5 to 3.8 m^3).

Figure 1: Installation of an empty 3.8 m^3 'Tuff Tank'

Figure 2: Neutralisation process within a 3.8 m3 'Tuff Tank'

Figure 3: Storage of latrine wastewater in a 2.4 m^3 'Tuff Tank'

Following detailed discussions with relevant experts in the field (namely Tom Curtis, Professor of Environmental Engineering at the University of Newcastle, and Huw Taylor, Professor of Microbial Ecology at the University of Brighton, both in the UK), two protocols were developed, based on previous research into low-cost physico-chemical treatment of wastewaters (Taylor *et al*., 1994). Adapted protocols based on these studies were tested on wastewater generated at the Delmas 33 and Tennis Court CTCs.

The primary objective of treating CTC wastewaters must always be a significant reduction in the number of the cholera pathogen (*Vibrio cholerae*) to levels that do not pose an additional transmission pathway for the disease in the local community. It should however be pointed out that effective wastewater treatment is one part of a multiple barrier approach to disease control (Curtis, 1996)

Disinfection of the wastewater, rather than sterilisation, should therefore be the operational objective, and the aim of disease control should of course consider the local context with regard to the proximity of local communities, sources of drinking water and hygiene behaviour.

Wastewaters of human origin may be made less hazardous to human health through engineering interventions, firstly by physical separation of the pathogen from the waste stream; and secondly by destruction of the pathogen itself. Within these two approaches, several mechanisms may be utilised, namely:

- Physical separation: Coagulation/flocculation, sedimentation, filtration, etc.
- Pathogen destruction: Heat, desiccation, chemical oxidation, UV radiation, pH stress, etc.

Whereas the first of these approaches certainly results in a final effluent containing significantly fewer pathogens, if adequate destruction of the pathogen is not incorporated into the process, the separated sludge component will contain very high levels of infective organisms.

The optimal pH level for survival and growth of *Vibrio cholerae* is between 5 and 9.6 (Curtis*, 1996*).

Therefore, one option for *V. cholerae* destruction is either to raise or lower the pH level of the wastewater to above or below this optimal range for growth.

The second objective of the treatment process is the reduction of the organic load. This is achieved through assisted sedimentation.

The pH is also adjusted to neutral at the end of the process in order to dispose of the water safely.

Method A

The first treatment tested at an operational scale utilised hydrated lime ($Ca(OH)_2$) to achieve a two-fold effect:

- to raise the pH level of the wastewater to a point at which *V. cholerae* pathogens are destroyed; and
- to promote accelerated sedimentation of the suspended solids in the wastewater, through the production of a precipitated floc of magnesium hydroxide, thus effectively clarifying the wastewater and reducing its organic load.

A concentrated lime slurry was added to the wastewater so as to initially encourage rapid mixing (for coagulation) and then to encourage slow mixing (for flocculation). The mixing mechanism is then switched off and the wastewater is left to sediment for approximately twelve hours. The supernatant is then removed to a separate tank where hydrochloric acid (HCl) is used to neutralise the wastewater (i.e., so as to achieve a pH level in the range 6 to 8), so that the effluent can be infiltrated into the soil with limited damage to the soil environment.

Method A with the addition of magnesium sulphate

The high pH lime coagulation-flocculation process (Method A) relies on the presence of an excess quantity of magnesium cations in the wastewater, which are flocculated as insoluble magnesium hydroxide $Mg(OH)_2$ as the pH level rises above 11. A variation on Method A involves adding a specific amount of magnesium sulphate, in addition to the hydrated lime, in order to maximise the production of a precipitated magnesium hydroxide floc, and hence to increase the removal of smaller particles (including *V. cholerae*) by adsoption during the flocculation stage.

Addition of a specific quantity of this chemical (which can be determined through the execution of a series of jar tests before treatment is undertaken) was observed to improve notably the quality of the treated water.

Note: the efficacy of the process also depends on the level of bicarbonate 'alkalinity' which should ideally also be monitored.

Note: this modification of Method A is at an early stage of development and the authors are currently investigating this approach further.

Method B

The second treatment tested on an operational scale utilises hydrochloric acid (HCl) to decrease the pH level of the wastewater to lower than 4, so as to destroy *Vibrio cholerae*.

The wastewater is acidified to pH 4 and after twelve hours contact, the wastewater is returned to neutral pH by the addition of hydrated lime. Coagulation, flocculation and subsequent sedimentation is achieved by the addition of a coagulant such as aluminium sulphate. Sedimentation takes approximately two hours. This is the minimum recommended time for sedimentation, sufficient to have an excellent performance in terms of solid removal; longer sedimentation times (e.g. one night) can be of course considered. It is important to note that the improvement in the quality of the final effluent for sedimentation times higher than two hours was observed to be very limited.

The treated wastewater supernatant can then be disposed of safely.

Various sources of wastewater were generated at the *Médecins Sans Frontières* CTC.
The following sources were considered highly contaminated and requiring treatment:

- Latrines;
- Showers (*de facto* often used as latrines);
- Contents of stool buckets deriving from the hospital tents;
- Wastewater from cleaning buckets; and
- Wastewater from floor disinfection

The following sources were considered to be not highly contaminated and were therefore disposed of in infiltration trenches without further treatment:

- Laundry waters; and
- Hand washing points

A dedicated CTC wastewater network was installed. The goal was to collect the wastewater at various points around the facility, which could then be pumped to the ‘treatment zone’.

Detailed procedure

Materials needed

In addition to all plumbing, storage space and other required hardware, the following equipment is required for operation and monitoring of the system:

- 1 x rigid kit water tank, 30 m^3 (KWATKTANF30)
- At least 4 x 4 m^3 rigid plastic tanks ('Tuff Tank' type)
- 1 x kit, motor pump, petrol, 30 m^3/h (KWATKPUP30-)
- Plastic buckets (of at least 18 litres capacity) with lids (to be used for initial sampling)
- Permanent marker pens (to mark buckets, samples, etc.)
- Graduated cylinder (1000 ml)
- Plastic scoop for hydrated lime
- Electronic pH meter*
- COD field testing kit*
- Total suspended solids (TSS) field testing kit*
- Aluminium residual test kit *
- Electronic analytical scale* (for TSS)
- Membrane filtration units and vacuum pump (or Delagua kit)* (for testing *E.coli*)
- Electronic turbidity meter*
- 200 L plastic drum with tap for preparation and addition of lime
- Hand pump for addition of acid (with acid resistant components)
- Two hand-set VHF radios for communication during wastewater pumping (communication between pump operator and wastewater treatment site manager).
- Personal Protective Equipment (PPE) :
    - Mask, gas, EN 148-1 connection (PSAFMASG1-)
    - Protective overall, hooded, s.u.(??), XL (ELNOVER2XL)
    - Protective face shield(PSAFFACE01-)
    - Protective apron, plastic (ELNAPRP1P-)
    - Gloves, chemically resistant, long sleeves, pair (PSAFGLOVC1-)
    - Boots, rubber, pair, size 44 (ALFBOOR44-)
    - Respirator, FFP2, disposable (PASFMASP02-)
    - Cartridge filter for gas mask (Uranus A2B2E2K1), (Type E or P; EU regulations)

Consumables required

- Hydrated lime $Ca(OH)_2$
- Concentrated hydrochloric acid (HCl) (also referred to as muriatic acid)
- Calcium hypochlorite (65%)
- Aluminium sulphate $AlSO_4$ (Method B)
- Magnesium sulphate $MgSO_4$ (modified Method A)
- 1 L plastic containers to collect samples
- Glass fibre filters (GF/FC 2.5 cm Whatman for total suspended solids (TSS) analysis
- 45 micron sterile filters (for bacterial enumeration by membrane filtration)
- Sterile absorbent pads 45 mm diameter (for bacterial enumeration)
- Lauryl sulphate broth powder (for enumeration of presumptive *Escherichia coli*)
- Lighter or matches (for sterilisation of equipment used for microbiology)
- Methanol (for sterilisation of microbiology equipment)
- Distilled water (for cleaning of instruments and dilution of samples)
- Buffers (7.0 and 4.0) and KCl solutions for pH meter calibration and electrode protection.

Safety recommendations

It is important always to have constant access to a supply of 0.2% chlorine solution to deal with any accidental spills or wastewater leaks , as well as 0.05% chlorine solution for hand washing, plus a plentiful supply of drinking water to rinse skin that may come into contact with hazardous chemicals (e.g., acidic and alkaline solutions and powders).

It is essential that only authorised personnel are allowed within the (fenced) site. All personnel on site must wear protective gear appropriate to the task being undertaken.

Protocol A: High pH physiochemical treatment

<u>Part One:</u> Alkalinisation, coagulation-flocculation and sedimentation

1. Calibrate pH meter (twice a week)
2. Fill the 30 m^3 tank to a maximum of 2/3 of total volume
3. Mix wastewater by re-circulation using an appropriate submersible pump in order to obtain a homogenous mix
4. For comprehensive monitoring, test the following parameters in the influent wastewater:
    - pH
    - turbidity
    - TSS
    - COD
    - Presumptive *E.coli.*

5. Create the lime slurry: Add hydrated lime to water at a concentration of approximately 20 g/L in a 200 litre drum. The drum should be placed on a platform above the reactor tank, directly above the influent pipe. Using the pump, continue to re-circulate the water in the tank.
6. Add lime slurry to wastewater so as to achieve flash-mixing (inflow hose running parallel to tank wall by means of an elbow) until pH of the circulating wastewater is greater than or equal to 11.4.
7. Continue pumping slowly for at least five minutes in order to achieve the slow mixing that encourages flocculation.
8. Switch off the pump and leave wastewater to sediment for twelve hours
9. For comprehensive monitoring, test the following parameters in the resulting supernatant:
    - pH
    - turbidity,
    - COD
    - TSS
    - Presumptive *E.coli*

10. Measure the depth of sludge in the tank.

<u>Part Two:</u> Neutralisation

1. Carefully pump all the supernatant (taking care not to re-suspend the sludge) into another tank
2. Mix the supernatant and add acid until a pH level of lower than 8 is reached
3. Test the following parameters in this supernatant:

- pH (mandatory)
- turbidity (mandatory)
- COD (for a comprehensive monitoring programme)
- TSS (for a comprehensive monitoring programme)
- Presumptive *E.coli* (mandatory)

4. When test results indicate that the effluent has reached a satisfactory level (i.e.,turbidity less than 50 NTU, pH 6-8 and *E.coli* fewer than 1000 colony forming units/100ml), it can be disposed of in an appropriate manner*.

Expected results for this protocol

- Turbidity < 50 NTU

- TSS < 100 mg/l (removal rate of TSS: 90%)

- *E.coli* < 100 CFU/100 ml (removal rate of *E.coli*: 99.9%)

For general considerations regarding final effluent quality refer to Section "Final effluent quality guidelines"

Sludge removal

Our experience shows that about 6 % (v/v) of sludge can be expected from each batch of treated wastewater. Although the sludge has a relatively high water content, it is difficult to remove by mechanical means (sludge pump such as Libellula).

Ideally the sludge should be manually removed from the tank after each batch. It must be ensured that all staff involved in this operation are provided with, and use, adequate PPE clothing. Sludge should be stored for an additional three days (to continue the disinfection process at high pH) before being applied to drying beds with a sand base to aid dewatering and desiccation.

Dried sludge forms a "cake", which can then be placed in containers and disposed of to an appropriate landfill facility or organic pit. It can also be incinerated, but this can be quite a tedious process with its own inherent health and safety issues.

Protocol A with the addition of magnesium sulphate: High pH physiochemical treatment with increased floc production

<u>Part One</u>: alkalinisation

1. Calibrate pH meter (twice a week)
2. Fill the 30 m^3 tank to a maximum of 2/3 of the total volume
3. Mix wastewater by re-circulation using an appropriate submersible pump in order to obtain a homogenous mix
4. For comprehensive monitoring, test the following parameters in the influent wastewater:
    - pH
    - turbidity
    - TSS
    - COD
    - Presumptive *E.coli.*
5. A jar test is strongly advised at this point in order to determine the required amount of magnesium sulphate to be added. The amount required depends on the quality of the raw wastewater (with regard to its initial magnesium concentration and alkalinity level). As an indication we used 450 mg/l.
6. Create the lime slurry: Add hydrated lime to water at a concentration of approximately 20 g/L in a 200 litre drum. The drum should be placed on a platform above the reactor tank, directly above the influent pipe. Using the pump, continue to re-circulate the water in the tank.
7. Add the magnesium sulphate.
8. Pump slowly for five minutes to mix.
9. Add lime slurry to wastewater so as to achieve flash-mixing (inflow hose running parallel to tank wall by means of an elbow) until pH level of the circulating wastewater is greater than or equal to 11.4.
10. Continue pumping slowly for at least five minutes to achieve the slow mixing that encourages flocculation.
11. Switch off the pump and leave wastewater to sediment for twelve hours
12. For comprehensive monitoring, test the following parameters in the resulting supernatant:
    - pH
    - turbidity,
    - COD
    - TSS
    - Presumptive *E.coli*

13. Measure the depth of sludge in the tank.

Part Two: Neutralisation

1. Carefully pump all the supernatant (taking care not to re-suspend the sludge) into another tank
2. Mix the supernatant and add acid until a pH level of lower than 8 is reached
3. Test the following parameters in this supernatant:
    - pH (mandatory)
    - turbidity (mandatory)
    - COD (for a comprehensive monitoring programme)
    - TSS (for a comprehensive monitoring programme)
    - Presumptive *E.coli* (mandatory)

4. When test results indicate that the effluent has reached a satisfactory level (i.e., turbidity less than 50 NTU, pH 6-8 and *E.coli* fewer than 1000 colony forming units/100ml), it can be disposed of appropriately.

Expected results for this protocol

- Turbidity < 50 NTU**

- TSS ** < 100 mg/l (removal rate of TSS: 90%)

- *E. coli* < 100 CFU/100 ml (removal rate of *E.coli*: 99.9%)

** Turbidity and TSS values outlined here are the minimum requirement for safe disposal. In principle the addition of magnesium sulphate should produce lower values for turbidity and TSS compared to protocol A, but this treatment approach is still subject to further research.

For general considerations regarding final effluent quality refer to Section "Final effluent quality guidelines"

Sludge removal

Our experience shows that about 6 % (v/v) of sludge can be expected from each batch of treated wastewater. Although the sludge has a relatively high water content, it is difficult to remove by mechanical means (using a sludge pump such as 'Libellula').

Ideally the sludge should be manually removed from the tank after each batch. It must be ensured that all staff involved in this operation are provided with, and use, adequate PPE clothing. Sludge should be stored for an additional three days (to continue the disinfection process at high pH) before being being applied to drying beds with a sand base to aid de-watering and desiccation.

Dried sludge forms a “cake”, which can then be placed in containers and disposed of to a landfill facility or organic pit. It can also be incinerated, but this can be quite a tedious process with its own inherent health risks.

Protocol B: Low pH physiochemical treatment followed by coagulant-assisted sedimentation

<u>Part One:</u> Acidification

1. Calibrate pH meter (twice a week)
2. Fill the 30 m^3 tank to a maximum of 2/3 of total volume
3. Mix wastewater by re-circulation using an appropriate submersible pump in order to obtain a homogenous mix
4. For comprehensive monitoring, test the following parameters in the influent wastewater:
    - pH
    - turbidity
    - TSS
    - COD
    - Presumptive *E.coli.*
5. Add acid to the tank in order to reach a pH level of 4 (inflow hose running parallel to tank wall by means of an elbow)
6. Pump slowly for at least five minutes to mix the tank contents and achieve a homogenous ph level.
7. Leave wastewater to sediment for at least twelve hours
8. For comprehensive monitoring, test the following parameters in the resulting supernatant:
    - pH
    - turbidity,
    - COD
    - TSS
    - Presumptive *E.coli*
9. Measure depth of sludge in tank.

Part Two: Neutralisation

1. Carefully pump all the supernatant (taking care not to re-suspend the sludge) into another tank ($4m^3$).
2. Create lime slurry: Approximately 20g to 1 l of water for slurry
3. Mix the supernatant and add the lime slurry until a pH level higher than 6.0 is achieved
4. Prepare a solution of aluminium sulphate by dissolving 300 g of the powder in 1 litre of water.
5. Take four transparent beakers of 1 litre of wastewater and perform a jar test to determine the amount of coagulant needed to optimise the sedimentation process (around 100 mg/l of aluminium sulphate)
6. Add the determined volume of aluminium sulphate solution into each tank while mixing rapidly with a short stick for 5 minutes (flash mixing) followed by a slow mixing phase of about 20 minutes with a long stick (to improve formation of flocs)
7. Leave water for approximately two hours.
8. Test the following parameters in this supernatant:
    - pH (mandatory)
    - turbidity (mandatory)
    - COD (for a comprehensive monitoring programme)
    - TSS (for a comprehensive monitoring programme)
    - Presumptive *E.coli* (mandatory)

9. When results of tests are acceptable (turbidity < 50 NTU, pH 6-8 and *E.coli* < 1000CFU/100 ml), water can be disposed of.

Expected results for this protocol

- Turbidity < 20 NTU**

- TSS < 50 mg/l (removal rate of TSS: 95%)

- *E.coli* < 100 CFU/100 ml (removal rate of *E.coli:* 99.9%)

For general considerations regarding final effluent quality refer to Section "Final effluent quality guidelines"

Sludge removal

Our experience shows that about 6 % (v/v) of sludge can be expected from each batch of treated wastewater. Although the sludge has a relatively high water content, it is difficult to remove by mechanical means (sludge pump such as Libellula).

Ideally the sludge should be manually removed from the tank after each batch. It must be ensured that all staff involved in this operation are provided with, and use, adequate PPE clothing. . Sludge should be stored for an additional three days (to continue the disinfection process at high pH) before being applied to dryingbeds with a sand base to aid desiccation.

Sludge desiccation time in the drying beds can differ according to various parameters such as degree of ventilation, surface area dedicated to sludge desiccation, temperature, season, etc.

If the odour from the sludge drying process should become problematic for residents in the surrounding community, pure hydrated lime can be added to the top of the desiccation bed. Lime can significantly slow down the biological activity that in effect causes fermentation, putrescnce and bad odour.

It is not possible to prescribe here the quantity of lime that needs to be added to the top of the sludge bed. This must be determined empirically.

Dried sludge forms a “cake”, which can then be placed in containers and disposed of to an appropriate landfill facility or organic pit. It can also be incinerated, but this can be quite a tedious process with its own inherent health and safety issues.

Final effluent quality guidelines:

As noted earlier, wastewater treatment constitutes one part of a multiple barrier approach to the waterborne transmission of of *Vibrio cholerae*. Complete sterilisation of the wastewater from CTC is neither economically feasible or necessary to protect the public health. However the methods described here were shown to disinfect the wastewater (as indicated by substantial reductions in levels of the faecal indicator organism *Escherichia coli*). The authors suggest that the following effluent standards are both achievable and correspond to international norms for treated wastewater quality.

- Turbidity < 50 NTU
- TSS < 100 mg/l (removal rate of TSS: 90%)
- Presumptive *E.coli* < 100 CFU/100 ml. (removal rate of *E.coli*: 99.9%)

Further work is currently being planned by the authors to validate the removal rates achieved during operational research by controlled laboratory jar test studies. These studies will enable us to suggest further modifications to the treatment process to achieve improved removal rates more efficiently (e.g., reducing quantities of reagents used by modifying the mixing regime). It is also important that the relationship between levels of *Vibrio cholerae* and *E. coli* is demonstrated at each stage of the treatment process (Both Protocols A and B). This will initially be achieved by spiking municipal wastewater with a non-toxigenic strain of *Vibrio cholerae*, but in the longer term these experiments should be undertaken using CTC wastewaters.

Wastewater analysis procedures

The following tests should be undertaken on samples of wastewater taken at different stages of the treatment process.

pH level

Definition:

pH is a measure of the acidity of an aqueous solution ($-\log_{10} [H^+]$). Distilled water has a pH level of 7.0 at 25 °C. Solutions with a pH level lower than seven are said to be acidic and solutions with a pH level greater than seven are basic or alkaline.

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Measuring the pH level of the wastewater at each stage of the treatment process allows the operator to ascertain the correct amount of chemicals to be added at each stage.

The pH level should be measured at the following points in the process:

a) In the raw wastewater

b) Several times during the **first** alkalinisation process (protocol A), or the acidification process (protocol B), in order to judge the quantity of additional chemical needed to attain the target pH level for effective disinfection (and in the case of Protocol A, effective coagulation). Typically, working with a wastewater volume of 15 m^3, the authors recommend that the pH level is measured after each addition of approximately 2 kg of hydrated lime, and after each addition of approximately five litres of acid. The frequency of measurement should be slightly increased around the pH neutrality 'zone' (pH 6 to 8) because at this level, change in pH level takes place more rapidly.

c) Following sedimentation (after approximately twelve hours in the case of Protocol A)

d) Several times during the neutralisation phase in order to monitor the quantity of chemicals to be added and to ensure that the pH level reached is compatible with safe infiltration of the effluent into the environment. As mentioned above, it is recommended that the pH level is measured after the addition of approximately each 2 kg of hydrated lime and after the addition of approximatively each five litres of acid. The frequency of measurement should be slightly increased around pH neutrality (pH 6 to 8) because here pH level changes more rapidly in response to chemical addition.

e) At the end of the complete treatment before soil infiltration of the effluent

Turbidity

<u>Definition:</u>

Turbidity is the degree to which water loses its transparency as a result of the presence of suspended particulates.

Turbidity levels give a clear indication of how effective coagulation-flocculation and sedimentation processes have been in removing colloidal particles.

Turbidity levels can also give a first indication of how effective coagulation-flocculation and sedimentation processes have been in reducing COD and BOD levels. The reason is that, a relevant part of the organic matter present inwastewater (measurable as COD or as BOD) is present in the form of colloidal particles. These particles have the property of preventing the transmission of light through a water sample. In other words, these particles increase the turbidity. The measurement of turbidity is therefore an indirect and effective way to monitor quickly the COD or the BOD concentration present in the wastewater before and after treatment, and therefore to assess the effectiveness of the treatment regarding COD and BOD removal.

A low turbidity effluent (< 50 NTU) is required to reduce the risk of clogging the infiltration trench if infiltrated into the ground, or to improve the aesthetic characteristics of the effluent if disposed into surface waters such as a stream or lake.

Turbidity can be measured quickly and easily using a turbidity tube or, better still, using an electronic turbidity meter. TSS and COD processes are more tedious .

Turbidity levels should be measured:

a) In the raw wastewater

b) Following the twelve hour sedimentation stage

c) Following neutralisation

d) At the end of the complete treatment process before infiltrating the effluent

Thermotolerant Coliforms (TTC) and/or *Escherichia coli* (*E. coli*)

<u>Definitions:</u>

Thermotolerant coliforms and *E. coli* are standard indicators of faecal contamination which are used widely in the monitoring of drinking water and wastewater treatment processes.

The procedure described here uses the Delagua kit to enumerate thermotolerant coliforms per 100 ml wastewater sample. *E.coli* are the most significant group of bacteria within the thermotolerant coliform group. Therefore, it is acceptable in the circumstances of operational monitoring to classify the typical colonies as 'presumptive *E. coli*'.

A significant reduction in levels of *E.coli* during the processes described here can be considered to correspond to a significiant reduction in levels of *V. cholerae*. Although the true relationship between removal/disinfection rates of faecal indicator bacteria (in this case *E.coli*) and the pathogen of concern should be elucidated further, especially at high and low pH levels. We can reasonably assume that several log removals of the indicator organism correspond with similar removal rates for *Vibrio cholerae.*

We recommend that levels of *E.coli* are measured at at least two points during the treatment process:

a) In the raw wastewater

b) At the end of the complete treatment process before infiltrating the effluent

See attachment for the complete procedure for *E.coli* testing in a field laboratory.

Oxfam- Delagua
kit.pdf

COD

Definition:

The chemical oxygen demand (COD) test is commonly used in environmental chemistry to measure indirectly the quantity of organic compounds in water.

COD levels are expressed in milligrammes per litre (mg/L), which indicates the mass of oxygen consumed per litre of solution.

In order to measure the COD, the water sample is usually oxidised using a strong chemical oxidant, and the oxygen consumed by the reaction during the process is recorded as the COD of the sample (in mgO_2/L). Alternative measurement methods are available. However, these methods do not determine the amount of oxygen consumed **directly** but rather **indirectly** by evaluating the change in the colour of the solution before and after the reaction. This approach was used by the team in Port-au-Prince and requires a spectrophotometer.

COD is used as a standard parameter of process efficacy in many wastewater treatment systems. The parameter is usually used in combination with the five day biochemical (or biological) oxygen demand (BOD_5) test.

BOD is defined as the quantity of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample over a specific time period at a defined temperature. This is widely used as an indication of organic contamination levels in waters and wastewaters. BOD can theforefore be used as a gauge of the effectiveness of wastewater treatment plants.

BOD_5 is a better indicator of the biodegradable organic load of a water or wastewater than COD, but is more difficult to perform and takes five days to obtain results, which is not ideal for the monitoring and daily management of a treatment plant. For these practical reasons, only COD measurement is recommended here.

The recommendation of the authors is to measure the COD twice during the treatment process:

a) In the raw wastewater

b) At the end of the complete treatment process before infiltrating the effluent

Total Suspended Solids (TSS)

Definition:

Total suspended solids is a water quality measurement usually abbreviated as TSS. This parameter measures the dry weight of organic and inorganic particulate matter suspended in the water that is trapped by a glass fibre filter of a specified pore size.

TSS of a water sample is determined by carefully pouring a measured volume of water (typically one litre; but less if the particulate density is high, or as much as two or three litres for very clean water) through a pre-weighed filter of a specified pore size, then weighing the filter again after drying to remove all water.

Filters for TSS measurement are typically composed of glass fibres. The gain in weight is a dry weight measurement of the particulates present in the water sample expressed in units derived or calculated from the volume of water filtered (typically milligrammes per litre or mg/l).

Total suspended solids (TSS) therefore represents the solid material, both organic and inorganic, suspended in the water. The parameter is related to turbidity but is more tedious to measure. Turbidity is mainly used to measure colloidal solids in drinking water treatment processes while TSS measurement is used widely in wastewater treatment. TSS levels measured at different stages of the treatment process indicate the efficacy of the sedimentation process. We recommend to use a standard method such as that described in Standard Methods for the Examination of Waters and Wastewater (APHA, 2010 - www.standardmethods.org)

Thus, we suggest that both TSS and COD should be measured at least twice during the treatment process : (a) in the raw wastewater and (b) in the final effluent.

See attached Excel template.

Template.xls

Safety and PPE

When handling hydraulic lime $Ca(OH)_2$:

- Gloves (chemically resistant)
- Respirator (FFP2)
- Plastic apron
- Rubber boots
- Laboratory coat

When handling hydrochloric acid (muriatic acid, HCl):

- This must ALWAYS be undertaken outside in a well-ventilated area, upwind of the prevailing wind direction. This applies to both dilution and application.
- When using acid to lower the pH level, the clarified wastewater should be circulated over the tank.
- Dilution should always be undertaken by adding acid to water. NOT vice versa.
- Acid must be store in a well-ventilated, cool place, away from metals and any other chemicals, especially oxidising agents such as calcium hypochlorite (also referred to as HTH), which must be stored separately.

With regard to PPE, use of the following items is recommended:

- Goggles
- Face shield
- Gloves (chemically resistant)
- Plastic apron
- Laboratory coat
- If vapours or gases are likely to be present, a gas mask with cartridge filter (Uranus A2B2E2K1), (Type E or P; EU regulations) will be required. However, these conditions are not anticipated if all work is undertaken outdoors.

References

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2) Standard Methods for the Examination of Waters and Wastewater

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