

Water treatment

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In humanitarian programmes, the main objective of water treatment is to protect consumers from pathogenic micro-organisms and unpleasant-tasting impurities. Problems with toxic substances are much less frequent than microbiological problems, and are not covered in this book.

Water treatment requires equipment, skills, regular surveillance and maintenance. The smallest weakness in the treatment procedure can endanger the safety of the water supplied and the process must be closely controlled if this represents a major risk on health. This is why the alternative of home water treatment alone must be very carefully assessed as it is more difficult to monitor than collective water treatment.

1 Treatment procedures

1.1 Choice of procedures

1.1.1 TREATMENT OPTIONS

A treatment procedure is a specific technique which allows a particular characteristic of the water to be corrected. The choice of procedure or combination of procedures is therefore made depending on the parameters to be treated (Table 12.I).

Table 12.I: Water treatment procedures.

Turbidity	→	storage/sedimentation – flocculation/sedimentation – simple filtration
Faecal pollution	→	disinfection – slow sand filtration
Iron, manganese	→	aeration then sedimentation or simple filtration

1.1.2 RAPID ANALYSIS

Quick analysis of untreated water allow parameters to be corrected, and an estimation of the necessary quantities of reagents to be made. Once the treatment process is started, a check on the quality of the raw water (before treatment) allows the change in water characteristics to be measured, and the treatment to be adjusted accordingly. This is particularly useful for surface-water treatment stations installed during an emergency. Water-quality parameters are given in Chapter 4.

The level of general pollution of the water to be treated (organic matter, oxidisable matter, micro-organisms etc.) can be quickly estimated by the chlorine demand (See 2.4.1). Water without any oxidisable matter has no chlorine demand, whereas polluted surface water can have a chlorine demand of up to 8 mg/l. This parameter, which is not very accurate, must be used essentially for monitoring the quality of untreated water over time. In the field, the chlorine demand is measured following the same procedure as for free residual chlorine (see Section 2.4.3).

Bacteriological analysis of the water gives a partial picture of the level of faecal pollution (see Chapter 4), and generally confirms the need for disinfection. This analysis is also used routinely to monitor the effectiveness of treatment procedures.

Turbidity results from the presence of particles in suspension in the water (organic debris, clay, microscopic organisms etc.). Strong turbidity protects the micro-organisms fixed on the particles from the disinfectant: turbidity must therefore be as low as possible to permit thorough disinfection (Table 12.II).

Table 12.II: Scale of turbidity values.

NTU < 5	Colourless water, which can be directly disinfected or filtered
5 < NTU < 30	Slightly turbid water, which requires some treatment (flocculation, sedimentation, filtration) before disinfection
NTU > 50	Turbid water, which requires some treatment (flocculation, sedimentation, filtration) before disinfection

The pH must be between 6 and 7.5 (Degrémont, 1989) for effective application of the coagulant aluminium sulphate. If this is not the case, it is necessary either to correct the pH, or to use a different coagulant (such as iron salts).

1.2 Pre-treatment

When water has to be treated, it is essential to remove suspended matter. Some simple techniques help to eliminate debris and large particles (vegetable debris, floating wood, sand) from surface water.

1.2.1 PUMPING INTAKES

In the case of surface-water pumping, it is essential to position the suction pipe correctly. There are several ways in which this may be done.

The use of a suitable strainer or screen, with a mesh between 5 and 20 mm, removes the largest floating or suspended particles. This mesh size, which depends on the size of the particles to be removed, must allow an entry rate of water into the strainer of less than 70 cm/s, to avoid excessive head-losses. The strainer must be located in the middle of the water with a floating device (steel drum, buoy or raft).

A filter trench (or infiltration gallery), dug in the stream alluvial deposits and filled with round stones of 10-20 cm of diameter, is an effective pre-filter technique. The pump strainer is installed in a well, made from a concrete ring or steel drum, located at the end of the trench. All or part of the filter trench and well may be built in the river or lake bed itself, or on the bank.

It is also possible to place a coarse PVC screen in the trench, with a filter layer packed around it, composed of 30 or 40 cm of pebbles 10 to 20 cm in diameter. The PVC screen is then directly connected to the pump suction end. This has the advantage, compared with the simple filter trench, of being able to be cleaned by backwashing with the pump.

1.2.2 STORAGE AND PLAIN SEDIMENTATION

This technique removes suspended matter and some pathogenic organisms. In fact, water is an environment in which the lifetime of these organisms is limited: according to WHO, a reduction of about 99% of faecal-indicator bacteria is reached after 3 to 4 weeks of storage. Nevertheless, the usual storage time is not long enough to remove all of them. During this storage time, sedimentation of larger pathogenic organisms also occurs, and they settle at the bottom of the reservoir.

Not all suspended materials settle easily, especially those that colour the water (colloids). It is therefore necessary to carry out a settling test in a jar: if after 1 hour most suspended matter has not settled, another technique, flocculation, must be used.

1.3 Flocculation and sedimentation

1.3.1 PRINCIPLE

Flocculation reduces the turbidity of the water by removing suspended matter, including colloids (especially clays and water-colouring matter) which are kept in suspension by electrostatic and hydration phenomena and are difficult or impossible to remove by plain sedimentation. Flocculation indirectly reduces the number of pathogenic organisms present in the water by settling them with the colloidal matter.

Flocculation consists of adding chemical products known as coagulants to the water. These neutralise colloids and encourage them to combine to form flocs, sufficiently large and free enough to be removed by sedimentation or filtration. The sediments, which contain the residues of coagulants and pathogenic organisms, are removed under standard hygienic conditions.

The most widely used coagulant, aluminium sulphate, $\text{Al}_2(\text{SO}_4)_3 \cdot n\text{H}_2\text{O}$, comes in the form of a powder or solid lumps. The lump-form, which is very difficult to reduce to powder and relatively insoluble, should be avoided. The factor limiting usage of aluminium sulphate is the pH of the water, which must be between 6 and 7.5 (Figure 12.1): if the pH is outside this range, flocculation may be poor and the quantities to be used very large. In this case, it is advisable to use another coagulant, such as ferric sulphate, $\text{Fe}_2(\text{SO}_4)_3$, which is active over a larger pH range (5 - 9).

Synthetic coagulants are more versatile and effective. Most are in liquid form, which can complicate their transport. Finally, there are also natural coagulants (plant seeds, fruit etc.) which may be appropriate at household level.

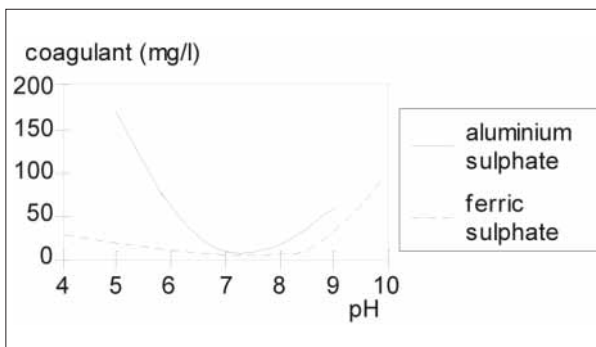


Figure 12.1: Quantity of coagulant to be used as a function of raw-water pH.

1.3.2 IMPLEMENTATION

Coagulants are not used directly, but in the form of a stock solution. The optimum dose required depends on the quality of the water to be treated, and must be determined by a jar test (see Section 1.3.2.2). To carry out coagulation on site, several steps are necessary.

1.3.2.1 Preparation of the stock solution

This 5% solution allows the coagulant to be used conveniently. It can be stored in a 20-l jerry can (or a 200-l barrel if large amounts are needed). Stir the solution thoroughly before each use.

The stock solution can be kept for 1 week.

1.3.2.2 Estimating coagulant dose (jar test)

It is not necessary to carry out this test every day if the quality of the water does not fluctuate rapidly. The test is carried out as follows:

– fill four plastic buckets with 10 l each of the water to be treated. With a syringe, add increasing doses of 5% stock solution to the buckets, so as to cover the usual dose range of 20 to 150 mg/l, for example:

- bucket 1: 4 ml of 5% stock solution, i.e. 200 mg of coagulant in 10 l of water, i.e. a coagulant (commercial product) concentration of 20 mg/l;
- bucket 2: 10 ml stock solution, i.e. coagulant concentration 50 mg/l;
- bucket 3: 20 ml stock solution, i.e. coagulant concentration 100 mg/l;
- bucket 4: 30 ml stock solution, i.e. coagulant concentration 150 mg/l.

– stir vigorously for 30 seconds, and then gently for 5 minutes;

– leave for 1 hour and then examine the samples visually: a floc looks like a piece of cotton wool soaked in water.

The smallest dose which gives good results is the recommended one. If the dose is too small, flocs do not form, are too small, or do not settle. If it is too high, traces of coagulant, which are difficult to remove, may remain in the water (especially aluminium).

1.3.2.3 Flocculation in the water tank

The formation of flocs is relatively quick, so much so that the coagulant stock solution must be mixed as quickly as possible in the water to be treated. Two methods of introducing the solution ensure quick and homogenous mixing (see Section 3): introduction into the pump suction pipe, or when filling the tank.

Floc formation and sedimentation can be improved by slow and regular stirring just after the rapid mixing. In circular tanks, placing the pump discharge pipe against the side of the reservoir imparts a circular movement to the water, which facilitates mixing. The time necessary for thorough sedimentation varies from half an hour to half a day, and can only be accurately determined by tests.

It is essential to transfer the treated water to a new reservoir before chlorination in order to avoid returning settled flocs to suspension during the mixing process. Furthermore, the coagulation sediments (which are toxic because of their aluminium content) must be emptied regularly, taking care to dispose of them without contaminating water resources or farmland. Table 12.III gives some essential information about aluminium sulphate, the most widely used coagulant.

1.3.3 WATER ANALYSIS

The pH of water treated with a coagulant is generally lowered (Box 12.1). It is therefore necessary to verify the pH at the time of treatment and, if necessary, to modify the dosages of coagulant or to correct the pH by adding another chemical.

Aluminium must be measured in the treated water if aluminium sulphate has been used. The WHO recommend a maximum aluminium concentration of 0.2 mg/l.

Table 12.III: Aluminium sulphate summary.

Characteristics

- Content of active product in the commercial product: about 17%
- Solubility limit: 688 g/l
- Density: 1 t/m³
- Acid reagent: causes a drop of pH in the water

Use of the commercial product

- Stock solution at 5% → 50 g/l → 1 kg/20 l
- Usual doses: 20 to 150 mg/l of commercial product → 4 to 30 ml of stock solution per 10 l of water to be treated
- 50 kg of aluminium sulphate treats about 300 to 2 500 m³ of water
- pH of the water to be treated: 6 to 7.5

Box 12.1

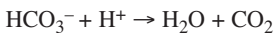
Coagulants and pH.

Acidification

Mineral coagulants (iron and aluminium salts) form a precipitate of hydroxides, creating some increase in acidity when they are dissolved in water:



This acidity can react with certain substances in solution, especially bicarbonate ions:



It can thus be compensated by the buffer capacity of the water (see Chapter 4) or, if necessary, by the addition of a base.

Correction of pH

Different chemicals can be used to raise the pH of the water:

(CaOH ₂)	Hydrated lime	not very soluble: 1.76 g/l at 10 °C
(CaO)	Quicklime	not very soluble: 1.3 g/l at 10 °C
(Na ₂ CO ₃)	Soda ash	soluble: 305 g/l at 10°C

Hydrated lime is the most common product, but it is difficult to use due to its low solubility. It is necessary to prepare a solution of 1 g/l and to stir it continuously until it is used.

Measuring the alkalinity of untreated water allows the calculation of the buffer capacity of the water, and therefore the quantity of alkali to be used. Nevertheless, an approximation accurate enough for testing is given by Degrémont (1989) and obtained by compensating the acidification induced by the aluminium sulphate by the addition of:

- lime: about a third of the dose of aluminium sulphate as solid commercial product;
- soda ash: 50 to 100% of the dose of aluminium sulphate as solid commercial product.

These dosages must be verified by tests such as jar tests. If lime is used to correct the pH before flocculation, the jar test can be carried out, with a fixed dose of aluminium sulphate and different doses of lime. It is also possible to vary the dose of coagulant depending on the dose of lime, in order to determine the best proportions.

1.4 Disinfection

There are several methods of disinfecting water, but the most widely used in emergency programmes is chlorination. It destroys pathogenic organisms present in the water* by blocking their enzymatic activity, and protects the water against recontamination during transport and storage. This residual disinfectant effect is its main advantage over treatment by ozone or ultraviolet rays.

1.4.1 PRINCIPLES OF CHLORINATION

Chlorine is an oxidant: in aqueous solution, it reacts with all the oxidisable matter present, both inorganic (iron, manganese etc.) and organic. This reaction can be expressed in terms of chlorine demand. If the quantity of chlorine added to the water is enough to fulfil this demand, the unused chlorine is found in a free form in the water: this is called free residual chlorine (Figure 12.2). The chlorine used to fulfil the demand is called combined residual chlorine.

To make sure that the quantity of chlorine added to the water to be treated is sufficient, it is necessary to check for the presence of free residual chlorine. Also, free residual chlorine is what protects the water against new forms of pollution which may appear after the disinfection process: this chlorine remains active for some time and can therefore kill new pathogenic organisms. Depending on storage conditions, free residual chlorine can persist from several hours to several days. A proportion of combined residual chlorine also remains as a disinfectant although far less effective than free residual chlorine. However, combined residual chlorine products are more stable and remain much longer than the free residual chlorine (useful in preventing post-contamination in piped systems).

Chlorination has many limitations. For adequate disinfection, turbidity must be less than 5 NTU. Occasionally, it is possible to chlorinate water with a turbidity of up to 20 NTU, but then the quantity of chlorine to be used is higher, the taste and smell of the chlorine are unpleasant, and disinfection is impaired. Pathogenic organisms fixed on the suspended matter are very difficult to destroy, and they may survive, even if there is free residual chlorine in the water after 30 minutes.

Chlorination is much less effective if the pH is higher than 8. This is because chlorine is present in different forms, depending on the pH of the water (hypochlorous acid (HClO) at low pH, hypochlorite ions (ClO⁻) at high pH). Since the most highly effective form is hypochlorous acid, disinfection is better under acidic conditions (Degrémont, 1989).

Disinfection depends on two parameters: the dose of disinfectant and the duration of contact between the disinfectant and the water (contact time). All the doses given in this chapter are calculated for a minimum contact time of 30 min, which must be maintained. If the contact time is less, the

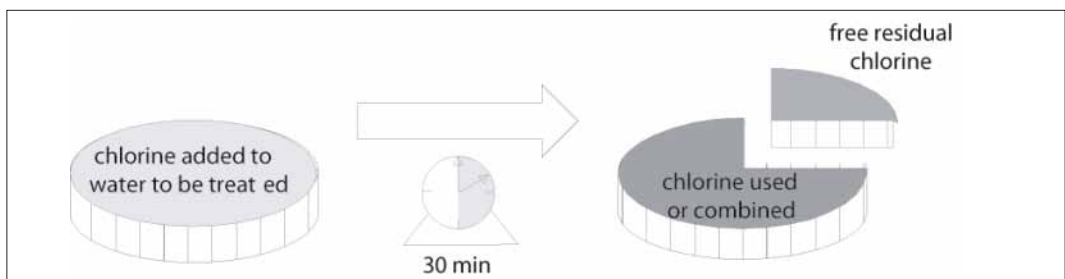


Figure 12.2: Chlorine in solution in water.

* According to WHO: normal chlorination conditions (0.5 mg/l of free residual chlorine, at least 30 min of contact, pH lower than 8 and turbidity less than 1 NTU) reduces the number of *E. coli* and certain viruses by much more than 99%, but has far less effect on the number of protozoan cysts and oocysts.

chlorine dose must be higher. It is considered that the product [contact time (min) x free residual chlorine (mg/l)] must be around 15 mg/l.min: about 1 mg/l.min is enough to destroy 99.9% of a population of *E. coli*, but about 10 times more is necessary for poliovirus 1 (Degrémont, 1989).

Chlorination must not be carried out in uncoated or unlined metallic containers, since the chlorine will oxidise the metal. In emergencies, it is possible to use enamelled or painted metal recipients (food-grade paint), but ideally plastic should be used.

Chlorine gas is difficult to use in emergency programmes. Chlorine-generating products, which liberate chlorine in aqueous solution, are therefore used. These products occur in different forms (Table 12.IV), and their active chlorine concentration may be expressed as follows:

- in percentage, where 1% = 10 g/l;
- in degrees of chlorine, where 1° Cl = about 3 g/l;
- in milligrams per litre, where 1 mg/l = 1 ppm = 0.0001%.

Preferably, high-test hypochlorite (HTH) should be used: it keeps well (loss of 2% of chlorine per year) in a non-metallic, hermetically sealed container, away from light and heat. It is nevertheless very corrosive and must be handled with great care (in case of contact, rinse thoroughly with water). HTH is subject to very strict air transport regulations and can only be transported in special containers.

Table 12.IV: Chlorine-generating products.

Chlorine-generating product	Active chlorine content	Comments
Calcium hypochlorite (e.g. HTH)	70% in powder	Preferable for collective treatment
Sodium dichloro-isocyanurate (NaDCC)	60% in powder 1.5 g / tablet	In tablet form for household distribution
Sodium hypochlorite (e.g. Javel water 12 or 15 °Cl)	4% or 5% in liquid	Keeps for a very short time after being opened
Chloramine T	25% in tablets	Reserved for individual usage

1.4.2 IMPLEMENTATION

1.4.2.1 Preparation of the stock solution

For regular chlorination of water, a 1% stock solution of 10 g/l of active chlorine, prepared from a chlorine-generating product is used (Table 12.V). It is easier to use a solution than a solid product. The stock solution must be kept in a sealed plastic jerry can, away from light, and for no more than three or four days.

To prepare 5 l of stock solution from HTH (Figure 12.3), mix 5 tablespoons of HTH in a plastic jerry can and shake well.

Table 12.V: Preparation of 1% solution.

As a guide to quantities: 1 tablespoon contains about 15 g or 15 ml of product, a teaspoon 5 g or 5 ml.

Product and active chlorine concentration	Dilution
Calcium hypochlorite - HTH at 70%	15 g/l
Sodium dichloro-isocyanurate (NaDCC) at 1.5 g per tablet	7 tablets/l
Sodium hypochlorite - Javel water 12 °Cl (15 °Cl)	250 ml/l (200 ml/l)

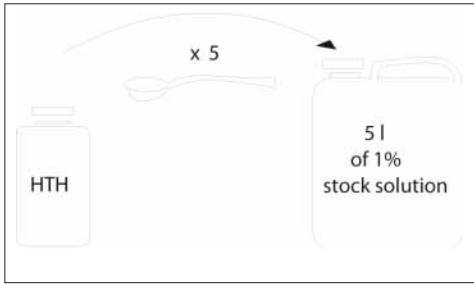


Figure 12.3: Preparation of stock solution of chlorine.

1.4.2.2 Dose required (jar test)

It is not necessary to carry out this test every day. On the other hand, free residual chlorine must be measured after each chlorination. The test is carried out as follows:

- Fill 4 plastic buckets, each with 10 l of water to be treated (Figure 12.4).
- With a syringe, add to each bucket increasing doses of 1% stock solution, so as to cover the usual dosage range of 1 to 5 mg of active chlorine per litre of water. For example:
 - bucket 1: 1 ml of 1% stock solution, i.e. 10 mg of chlorine in 10 l of water, i.e. chlorine concentration 1 mg/l;

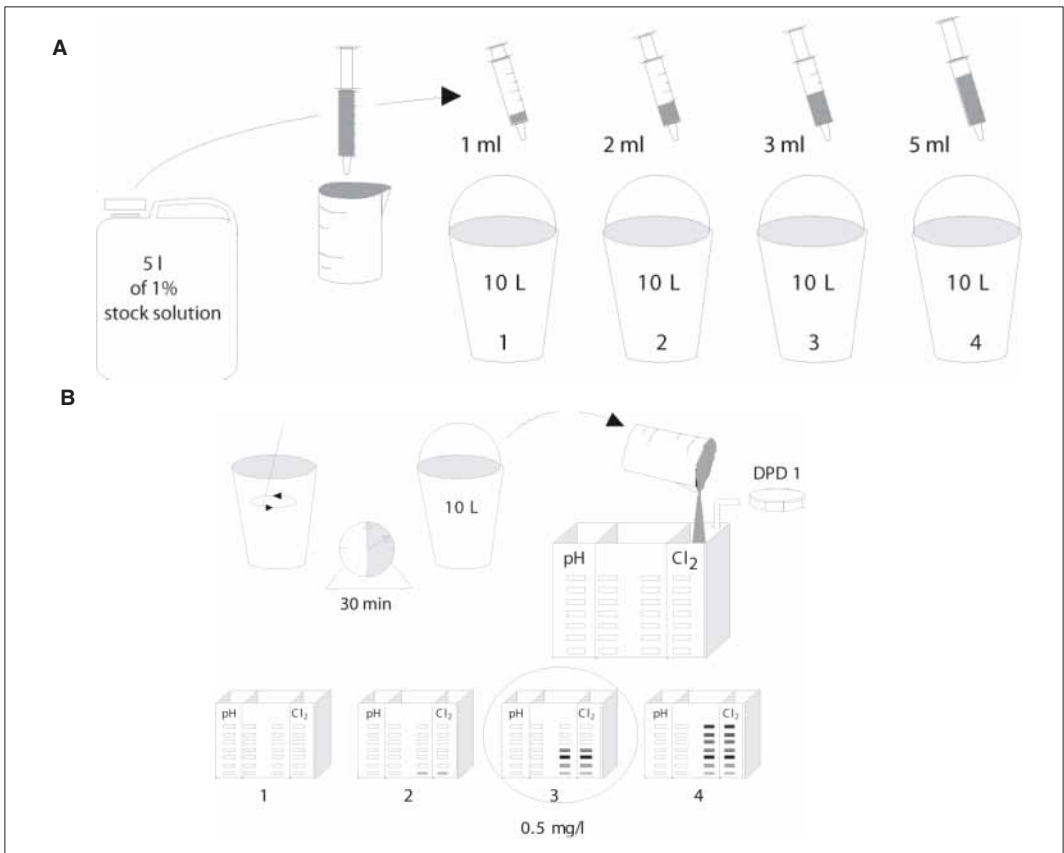


Figure 12.4: Jar test.
A: preparation of solutions. B: selection of dose.

- bucket 2: 2 ml of stock solution, i.e. chlorine concentration 2 mg/l;
 - bucket 3: 3 ml of stock solution, i.e. chlorine concentration 3 mg/l;
 - bucket 4: 5 ml of stock solution, i.e. chlorine concentration 5 mg/l.
- Stir vigorously and leave to work for 30 min.
- Measure the free residual chlorine and choose as a reference the dose which allows between 0.5 and 1 mg/l of free residual chlorine to be obtained.

1.4.2.3 Chlorination in the tank

To ensure good mixing, the solution is added when the tank is being filled. For large volumes of water, it is possible to use an automatic feeder (see Section 3). After 30 min contact time, the free residual chlorine is measured.

The main properties of HTH, the most widely used chlorine-generating product, are summarised in Table 12.VI.

Table 12.VI: Summary of properties of HTH.

Properties

Active chlorine content in commercial product: about 70%

Solubility limit: 225 g/l

Alkaline reagent: causes an increase in the pH of the water

Use of the commercial product

1% stock solution → 15 g/l → 1 tablespoon/l

Usual doses: 2 to 15 mg/l of HTH → 2 to 15 ml of stock solution per 10 l of water to be treated

1 kg of HTH treats 50 to 500 m³ of water

pH of the water to be treated < 8

1.4.3 MEASUREMENT OF FREE RESIDUAL CHLORINE

Free residual chlorine must be measured regularly after the water has been disinfected with chlorine: it is the only way of ensuring that disinfection has been effective. This analysis must be carried out in different parts of the water-supply system: at the outlet of the disinfection tank, at the taps, and in household water-storage containers. It is essential to know the value of free residual chlorine at the point of consumption, that is, in the home. This free residual chlorine must be between 0.5 and 1 mg/l; a concentration of 0.5 mg/l is recommended.

The dosage is calculated as follows:

- rinse the pooltester (colour comparator) before use;
- dissolve one DPD1 tablet in the chlorine compartment and one phenol red tablet in the pH compartment (Figure 12.5);
- if the pH > 8, the free residual chlorine should be greater than 1 mg/l;

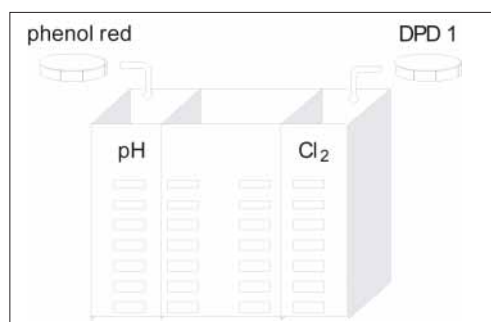


Figure 12.5: Pooltester.

Box 12.2

Boiling.

Boiling is an effective way of disinfecting water, that works even when the water is turbid. Nevertheless, this method has some serious disadvantages, which limit its usage to situations where no other technique is possible:

- on average, 1 kg of wood is necessary to boil 1 l of water;
- the water must be taken to a rolling boil, to ensure sufficient heating for pathogen removal. At high altitudes, boiling should be maintained for 2 min per 1 000 m above sea level;
- boiling deaerates the water and imparts a taste to it;
- as opposed to chlorination, no disinfectant remains in the water after treatment.

- if the chlorine generator is chloramine T, the residual chlorine is found only in combined form, so one DPD 1 tablet and one DPD 3 tablet are used;
- if the concentration of residual chlorine is very high, there may be a false negative result because the chlorine bleaches the reagent.

1.5 Filtration

There are different methods of filtration specific to different types of water pollution (Table 12.VII).

Table 12.VII: Various filters and their application.

Filtration technique	Application	Technical parameters
Ceramic-candle filters	Domestic use Treatment of turbidity Katadyn®-type filter: removal of pathogenic organisms	Filtration threshold: 0.45 µm Katadyn-type filter: 0.2 µm Flow: 1 to 4 l/h
Rapid sand filters	Treatment of turbidity Treatment of iron / manganese	Filtration rate: 10 m ³ /m ² /h Filter medium: sand 1-2 mm, UC* = 1.5 Thickness: 0.5 to 1 m
Slow sand filters	Treatment of faecal pollution	Turbidity < 20 NTU Filtration rate: 0.2 m ³ /m ² /h Filter medium: sand 0.2 mm, UC = 2 Thickness: 0.6 to 1 m sand + 0.4 m gravel

*UC = Uniformity coefficient – the ratio of sieve sizes through which 60% and 10% of the sand passes.

1.5.1 CERAMIC-CANDLE FILTRATION

Ceramic-candle filters are very suitable for domestic use, or in small health structures. The use of Katadyn®-type filters is recommended, since their fine filtration (0.2 µm) provides an effective treatment against pathogenic organisms (with the exception of viruses, whose removal is very limited).

1.5.2 RAPID SAND FILTERS

Basically, these filters provide mechanical water treatment and are used to treat turbidity higher than 20 NTU. The principle involves passing the water through a filter bed of fine sand (1-2 mm) of more or less uniform diameter (UC near 1.5). To prevent the filter from becoming blocked too quickly,

the flow rate of the water must not be too high: a flow of 10 m³/h per m² of filter surface is a good compromise. It is also possible to pass the water through a layer of coarser material (gravel) before the sand layer to pre-filter the water and slow down the blocking process.

For example, ACF used rapid sand filters in Juba, Sudan in 1991 to treat the water of the Nile, the turbidity of which is very variable. These filters, located in 200-l barrels, allow an acceptable level of turbidity to be achieved before disinfection. They are cleaned by back-washing.

Rapid sand filters can be used to collect flocs after flocculation. In this case, it is advisable to maintain a water flow rate of about 3 - 5 m³/h per m² of filter surface. Filters of this type can be built into Oxfam-type water tanks.

1.5.3 SLOW SAND FILTERS

Slow sand filtration consists of passing the water through a filter material, at a lower flow rate than in rapid sand filtration: a maximum of 0.2 m³/h per m² of filter surface is generally satisfactory. This slow rate allows the development of a great variety of organisms in the first few centimetres of sand. These organisms form a biological membrane, called a *schmutzdecke* (from the German: *dirt cover*), which decomposes the organic matter and provides an effective biological treatment against faecal pollution. Slow sand filtration can also be used to reduce turbidity, but the fineness of the sand only allows the treatment of fairly non-turbid water: it is not advisable to use a slow filter when the average turbidity is higher than 20 NTU. A turbidity of 150 to 200 NTU can be acceptable, but only for a few days, because of the risk of a rapid blockage.

When the filter is blocked, its flow decreases significantly. Maintenance then consists of removing the first 2 to 5 cm centimetres of sand, and then putting the filter into service again. When the thickness of the filter bed is down to around 60 cm, it is necessary to recondition the filter by adding clean sand. To avoid interrupting the water supply, two filters, which work in parallel or alternately, are usually installed.

The development and maintenance of the *schmutzdecke* requires particular conditions: it must always be under water, and the flow must be continuous and slow. It is therefore important to size the filter on the basis of demand (flow/area ratio), and to implement a system of flow regulation to control the level and flow rate of water through the filter. When these conditions are fulfilled, the biological membrane develops in 1 - 2 weeks.

Slow sand filters may be built using 70 m³ and 95 m³ Oxfam-type tanks (kit available).

1.6 Aeration

This technique, which is easy to use, accelerates the interaction between water and air. Atmospheric oxygen oxidises dissolved matter such as iron, which is sometimes present in excessive quantities in groundwater. Aeration also oxygenates the water and removes excess CO₂. Generally, aeration removes unpleasant odours and certain tastes.

A diffuser (like a shower head) can be installed at the inlet to storage tanks to facilitate aeration; this decreases the risk of anaerobic conditions and corrosion problems in the distribution system.

An aerator can be installed at the outlet of handpump, to remove iron. The precipitates formed as a result of aeration are removed by sedimentation or, even better, by filtration (Figures 12.6 and 12.7). Filters installed in Cambodia by ACF have reduced iron concentrations of 3 to 15 mg/l in some boreholes to less than 0.3 mg/l.

Nevertheless, the mechanisms which govern the precipitation of iron depend on numerous factors, such as temperature, redox potential, pH etc. Depending on the pH/redox potential combination, iron occurs in different forms, with certain complexes which are less easy to eliminate by a simple process.

Generally, it is considered that the higher the pH and the nearer the water to being saturated in oxygen, the more rapid will be the precipitation of the dissolved iron by aeration.

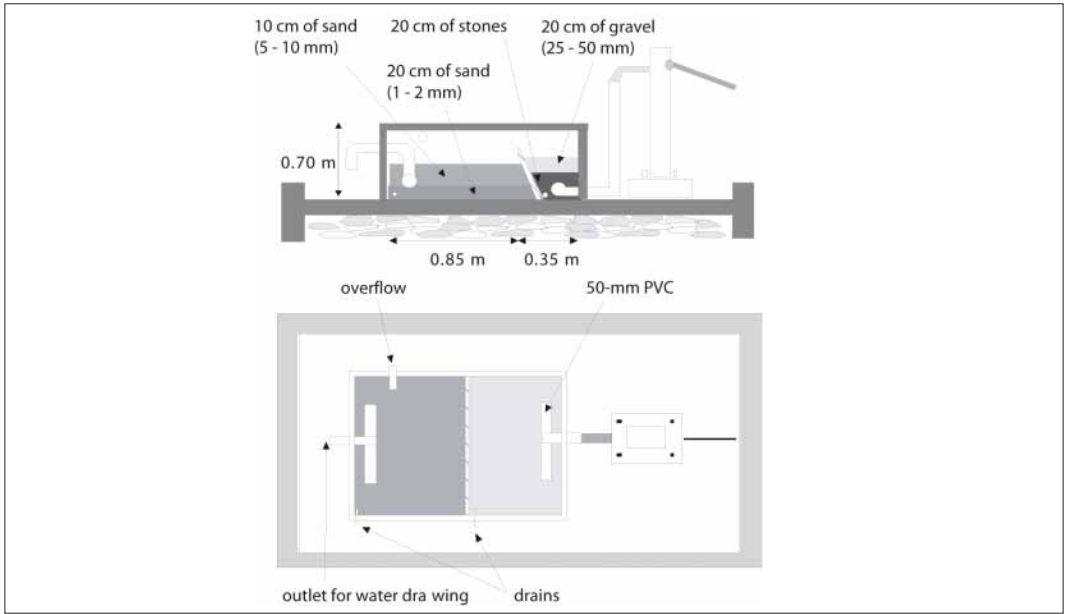


Figure 12.6: Removal of iron by aeration and filtration.

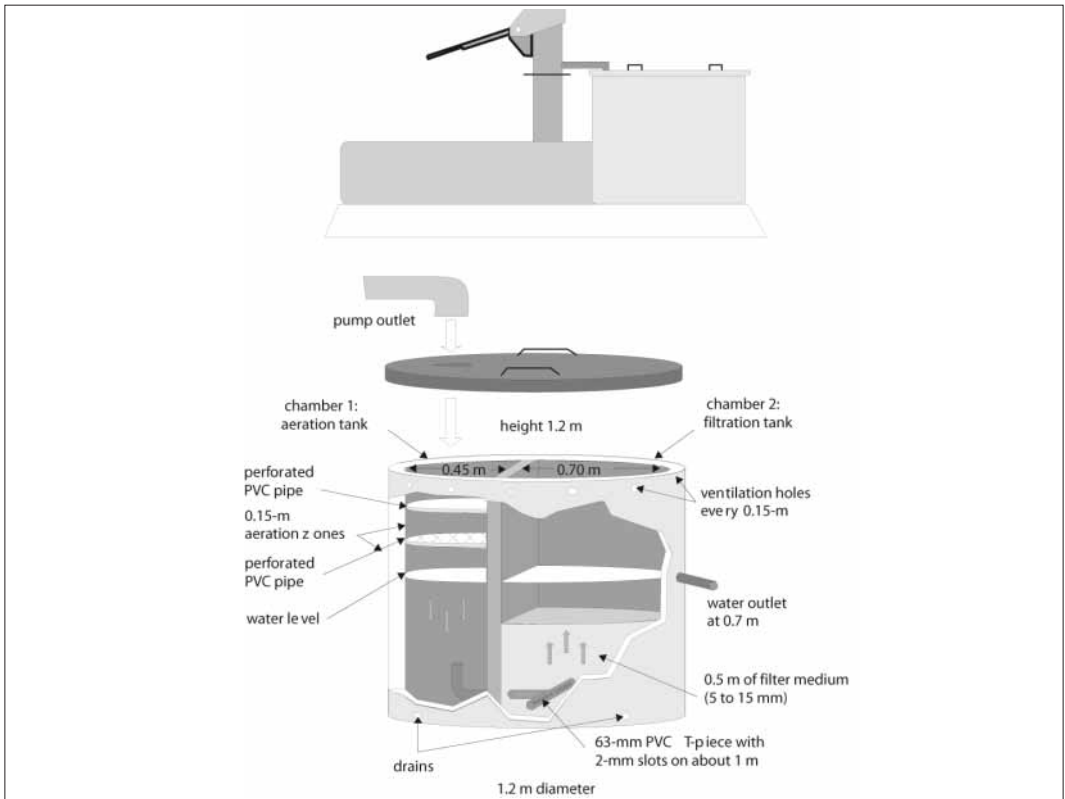


Figure 12.7: Removal of iron by forced aeration and filtration (using a concrete ring)
 (source: Partners for development, 1997).

2 Chemical dosing

To treat large volumes of water, a dosing system for aluminium sulphate and chlorine is installed. This provides effective control over the quantities of chemicals used, and therefore increases the efficiency of the treatment. Various techniques are possible.

Batch dosing consists of adding a constant volume of chemical to a known volume of water to be treated (Figure 12.8). This should be the first option to be considered, since it is the simplest to use. Nevertheless, it is not very satisfactory for flocculation, because mixing does not take place very quickly, and the rate of addition of coagulant is not constant, but decreases as the level of water in the chemical tank falls.

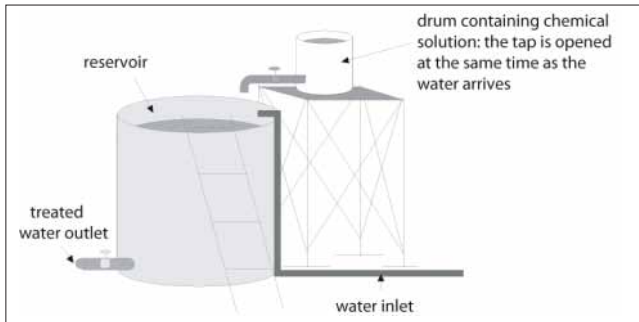


Figure 12.8: Addition of chemical to a treatment tank using a drum. The rate of addition of the chemical varies with the depth of solution in the drum.

Constant-flow dosing is carried out using a device which maintains a fixed level of solution in the chemical tank (Figure 12.9). This device can be made locally, or purchased (e.g. the SATTE gravity feeder).

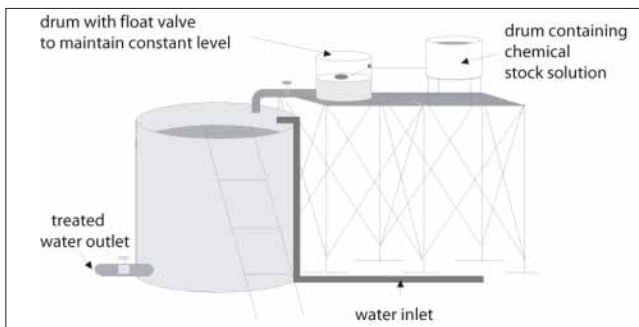


Figure 12.9: Addition of chemical at a constant rate.

Proportional-flow dosing is carried out with a feeder which modifies the injection rate of the chemical solution depending on the flow rate of water to be treated (Figure 12.10). There are several different kinds of equipment available, either dosing pumps or venturi devices. They include conventional dosing pumps, the Promix rotational dosing pump etc. The easiest to use is the Dosatron dosing pump, which can be mounted directly onto the pump discharge pipe.

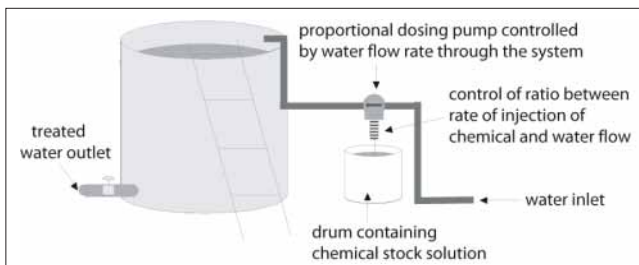
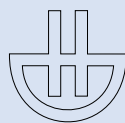


Figure 12.10: Proportional dosing.

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Water, sanitation and hygiene for populations at risk



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