Oxfam Guidelines

for

Water Treatment

in

Emergencies

Oxfam Humanitarian Department (new Oxfam logo)

CONTENTS

1. Introduction **4**

2. Assessing water quality **5**

2.1 Suspended solids (NTU) *6*

2.2 Microbiological (Faecal coliforms) *7*

2.3 Acidity/alkalinity (pH) *7*

2.4 Iron *7*

2.5 Salinity (TDS/Conductivity) *7*

2.6 Chemical 8

3. Treatment technologies **9**

3.1 Suspended solids removal/reduction *10*

3.2 Microbiological improvements *14*

3.3 pH adjustment 19

3.4 Iron removal *20*

4. Application of treatment processes 21

4.1 Bulk water supply to displaced populations *21*

4.2 Village level facilities 25

4.3 Household level arrangements 26

5. Installation strategy for bulk water supply 28

5.1 Acute phase *28*

5.2 Late emergency phase *29*

5.3 Post emergency phase *30*

6. Operation/management 32

6.1 Operation *32*

6.2 Monitoring *32*

6.3 Maintenance *32*

6.4 Management and Training *33*

Appendix 1 WHO water quality guidelines and Sphere standards 35

Appendix 2 Oxfam kits 36

Appendix 3 Treatment Monitoring forms 37

1. Introduction

These guidelines are partly based upon the use of Oxfam equipment packages, which are devised by the Oxfam Public Health Engineering Team to help provide a reliable water supply where mass displacement of people has occurred, e.g. as found in refugee camps and relief centres. Work with smaller communities who may not have been displaced from their homes, requires the use of different treatment approaches, although often using the same basic treatment methods. Equipment and approaches appropriate for these situations are also included.

The techniques and equipment described here reflect the most current practice of Oxfam GB humanitarian department. However a programme of ongoing applied research and development means that some of these approaches will be improved and modified in the future and these will be incorporated into subsequent revisions of these guidelines. Thus these guidelines serve in part to indicate future possibilities as well as describe what is currently possible.

The object of water treatment is to provide potable water, i.e. pathogen free and chemically safe, which is low in physical impurities and is also aesthetically acceptable to the consumer. However the greatest health risks in the overwhelming majority of situations where disasters occur are due to the presence of pathogens (microbiological contamination), where as chemical contamination is rarely on immediate health impact. Therefore these guidelines reflect this and focus accordingly. However it maybe that in the future that greater risks will be presented by chemical pollution of water and for example the extensive arsenic poisoning of groundwater in Bangladesh and Eastern India highlights that there can be other longer term detrimental health impacts.

In the early stages of water supply in an emergency, water quality (and quantity) may well fall below WHO recommendations, in which case the initial emphasis will be on raising both quality (and quantity) to come within acceptable limits in the ***shortest possible time***. It is also desirable in emergency situations to provide an extra level of protection in the water, in the form of a chlorine residual, to deal with contamination at a household level, e.g. in water containers.

Surface water sources often present the quickest option for water supply in the short term, but surface waters, unlike most ground waters, are much more prone to contamination by suspended solids and pathogens. This in turn often means that the biggest treatment problems encountered are the removal of suspended solids and providing means of effective disinfection.

In choosing a water source(s), the quality of raw water has to be balanced against the quantity available. From a health point of view, ***a larger quantity of relatively good quality water is better than a small quantity of very high quality water*** and this must be taken into account by choosing sources that have sufficient quantity of water available. In some instances, where good quality water is limited, it may be necessary to provide two different qualities of water to consumers, reserving water from a poorer quality source for washing, whilst the water from a small good quality source could be used for food preparation and drinking. This may create difficulties in keeping the two water qualities separate, both for bulk production and at a household level and will also need considerable support from a public health promotion program if it is to be understood, acceptable and successful. Also one large source of dirty water, which though requiring more treatment than several small cleaner sources, may be more convenient from a management point of view, because all pumping/treatment systems could be centralised at one location.

The selection of a water source depends not just upon its quality and quantity of water that needs to be supplied, but also its proximity to any proposed settlements, potential extraction difficulties and water rights, along with other issues. These guidelines will not go into these important factors that may influence the choice of a source, but rather concentrate solely upon treatment processes.

2. Assessing water quality

Summary

The main parameters to take into consideration in assessing water quality for immediate short term supply in an emergency context are; suspended solids, pH, the level of Faecal contamination (microbiological) and conductivity (a measure of salinity). Ground water sometimes has a high iron content and in dealing with waters from industrialised societies/locations, chemical contamination may also be of concern. Whilst relatively simple measures can be undertaken to treat water with high suspended solids and faecal contamination, adjusting pH is more difficult, though less likely to be a problem. However, treating saline water, which occurs in some areas, particularly in coastal areas and also dealing with chemical contamination is complex and not dealt with in these guidelines.

Contamination types:

Contam-ination Type	**Contam-ination Agents**	**Comments**
Physical	Particles and suspended solids	• As dramatic seasonal variations in the physical quality and quantity of river water are very possible in regions where heavy seasonal rains occur and/or where flow velocities are high, an assessment needs to take this into account. • A careful consideration of natural features can provide information when deciding where to site pumped intakes, i.e. does the riverbank have obvious flood terraces? • Try to establish if there is sufficient good quality of water does it deteriorate?
Biological	Faecal waste	• Faecal contamination is very dangerous indeed and can contribute to an outbreak of a water borne disease (including cholera and typhoid etc.) through the faecal-oral transmission route. If a protected source is available, say springs feeding a small stream or pond, use this source water.
	Algae	• Algae are difficult to remove using coagulants and can impart a bad taste to the product water. They can also block sand filters. Consider river bank or bankside filtration arrangements.
Chemical	Minerals, soil type	• The pH and salinity of different sources can vary, even though the sources may be in a close proximity. pH is an important factor where treatment involves the addition of coagulants (alum etc) as the quantity to be added is influenced by pH, as is the contact time for chlorine.
	Industrial effluents	• In a number of situations industrial or agrochemical pollution can be very marked. As the removal of such contamination requires high technology solutions, it is generally not possible to reliably achieve this during an emergency without use of more expensive and complex treatment plants. A check to ensure that insect larvae and fish life flourish in the water source can provide an indication of quality, e.g. by keeping fish in the header tank. • Look for signs of agricultural activities, empty chemical sacks etc. to establish if there is a potential for chemical contamination. Rivers and streams are more likely to be “self cleansing” than ponds and lakes.

Taste, Odours, colour:

It is often very difficult to identify the causes of tastes and odours in water, the likely sources of a few of the main problems are detailed in the following table (some of which may occur in the water treatment system itself).

Taste or Odour	Cause	Comments
Fishy or musty taste and odour	• Algae	Intake filtration and slow sand filtration can reduce, though not prevent, problems. Select raw water sources carefully.
Iron taste:	• Particulates caused by catchment geology. • Bacterial activity, common in old cast iron pipework.	Aeration and filtration can reduce this but also try to minimise turbidity. Iron bacteria can produce odour problems.
Sulphur taste, rotten egg smell	• Mineral content due to catchment geology	No real solution other than to minimise turbidity and particulate content of the water.
Brackish taste	• Sodium chloride (salt)	Check source water for salt source. Where wells near saline intrusion are used, care should be taken to avoid drawing saline water into freshwater lenses.
Mouldy taste and odour	• Moulds and actino-mucetes	Flush mains from time to time to avoid warm, stagnant zones in pipes.
Chemical taste	• Various classes of chemicals • Chlorine compounds	Most can only be removed with the help of activated carbon and pre-ozonation. Solvents and phenols can react with chlorine in water. Minimize chlorine dosing by treating the raw water to such a level that chlorine demand is minimized.
Colour	• May be caused by chemical or physical contamination	Removal of suspended solids will reduce colour effectively in many cases. A brown colour is produced by iron presence and has aesthetic implications, especially when cloths are washed.

2.1 Suspended solids (NTU)

NTU (nephlometric turbidity units) is a term is a measure of how much suspended matter such as organic material, e.g. algae, mud, rust etc., is carried in the water and has a bearing on the number of pathogens in the water and on how easy it is to disinfect water to kill off these pathogens. Whilst there is not an exact correlation between turbidity (measured in NTU) and suspended solids, the relationship is close and it is easier to measure turbidity using the turbidity tube. (Oxfam code FTT or found in the Oxfam DelAgua kit, code FK or the Measuring and Testing kit, code FMT.)

WHO recommends that if water is more than NTU 5, then some form of treatment to remove turbidity is necessary before the water can be effectively disinfected with chlorine. The NTU should be measured and if found to be higher than 5, then the next stage is to undertake a simple sedimentation test to establish if and how long it takes for the suspended solids to settle out. This will indicate likely settlement times, which in turn will help with sizing either sedimentation tanks or choosing a coagulation/flocculation-based system. A visual inspection can give an indication on whether particles are organic (algae etc.) which give a greenish/brownish colour or colloidal (very small) which appear as a fine suspension. These present greater difficulties for treatment, often requiring a coagulation/ flocculation stage in the process.

2.2 Microbiological (faecal coliforms)

Faecal coliform bacteria (>99% of which are E.coli) are an indicator of the level of human/animal waste contamination in water and the possibility of the presence of harmful pathogens i.e. microbiological contamination. A measure of this contamination will determine whether the water will need to be chlorinated or not according to WHO standards (0/100ml in all cases, though it is acknowledge that many supplies, especially rural water, will normally have low levels of contamination when chlorination is not employed2). It is recommended that chlorination should always be used in the early stages of an emergency situation and measurement of faecal coliforms will then not be essential. However the measurement of faceal coliforms can give an indication of likely chlorine demand (i.e. water with more faecal coliforms will generally require more chlorination, but it also indicates where more intensive treatment is needed) as well as enabling changes in raw water quality to be monitored. Faecal coliforms can be measured using the Oxfam DelAgua kit, (Oxfam code FK).

Studies show a high correlation between level of faecal coliform contamination and risks identified by a visual inspection of basic sanitary indicators, otherwise known as a sanitary survey. Put very simply, if there are numerous water contamination risks, such as latrines sited near water sources, uncontrolled open defecation by animals in areas where this can be washed into water sources etc., then there is likely to be a higher risk of contamination. Thus a simple visual inspection of water sources can be used as the first stage of assessment of likely water quality.

It is worth noting that sometimes the presence of coliform organisms (total coliforms) is used as an indicator. However coliform organisms may not always be directly related to the presence of facael contamination or pathogens in the drinking water, but the coliform test is still useful for monitoring the microbial quality of treated piped water supplies. The DelAgua test kit does not test for these and they are not dealt with further here.

2.3 Acidity/alkalinity (pH)

WHO guidelines recommend drinking water be in the range pH 6.5 - 8.5. Ideally the water will be fairly neutral with pH around 7 and this can be checked using the Pool Tester, (Code FPO, or found in the FK or FMT kits), which has a range from 6.8 - 8.2. Where the pH is outside this range, a pH stick type meter will be required (as found in the FMT kit).

Knowing the pH value is also important, as pH alters the effectiveness of two of the chemicals commonly used in water treatment. Chlorination is considerably slowed down when the pH is higher than 8, and either contact time or initial dose needs to be increased (see section on chlorination). The effectiveness of aluminum sulphate, commonly used as a coagulant, is severely effected by low or high pH, with a range of about pH 6.5 - 7.5 being optimum (see section 3.1.3. for more information).

2.4 Iron

This can be checked by use of a simple comparator which measures total iron content (included in Oxfam code FMT kit). Information from the local population, along with the tell tale signs of rusty/reddy brown stains on concrete/clothes etc., will provide further evidence of high iron levels. The WHO advised limit is 0.3mg/l.

2.5 Salinity (TDS/Conductivity)

The amount of TDS (Total Dissolved Solids) is a measure of the salinity of the water and it is measured using water (electrical) conductivity, though some meters give a direct reading of TDS (see relationship between TDS and conductivity in appendix 1). Changes in conductivity may indicate changes in the mineral composition of raw water or seasonal variations in reservoirs, though it may

also indicate sewage, industrial or agricultural pollution or intrusion of saline waters. WHO guidelines give a maximum value for TDS of 1000mg/l, although in some areas of the world higher values are accepted. A TDS stick meter (code FDS, also included in the FMT kit) is a convenient way of measuring this parameter. If the salinity of the water is approaching the WHO limit, then consideration should also be taken of the consumer's tastes, who may refuse to drink this water and instead go to other potentially contaminated waters. Where the salinity of water exceeds either consumer acceptability or WHO guideline, then an alternative source may be needed. Treatment processes to reduce the salinity of water are beyond the scope of these guidelines and, if possible, other sources should be located.

2.6 Chemical

Over and above the tests mentioned above, it might be appropriate to undertake the following water chemistry tests; Chloride, Sulphate, Nitrate, Hardness, Ammonia and Fluoride, which can all be undertaken fairly simply. Fluoride levels may also need to be checked, especially in the African Rift Valley and other areas known for fluoride problems. This level should not be above 1.5 mg/litre but higher levels may have to be accepted for short periods. In large areas of Bangladesh and Bengal in India, Arsenic is a major problem, but this is difficult to detect at lower concentrations and difficult to remove.

Many of these tests can be undertaken with a simple comparator, but it would often be better to use a dedicated kit such as Palintest 5000 Photometer and relevant reagents. These can be ordered if required, but are not that commonly used by Oxfam, as these chemical concerns are often of less health significance in the short term in an emergency situation and are also less often encountered.

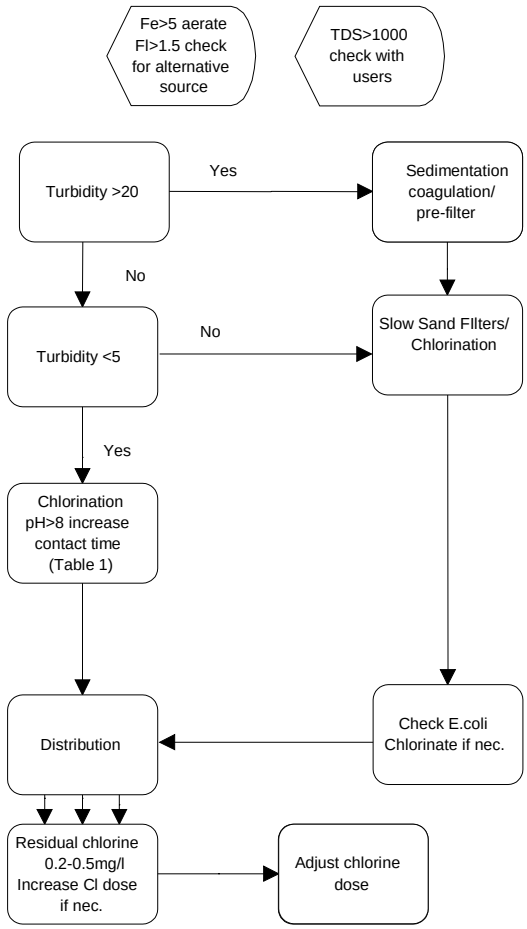
Where there are concerns over industrial and mining wastes and the possibility of these leaching into water systems, the following parameters could also be of concern; Nickel, Zinc, Chromium VI, Manganese, Copper, Lead, Mercury and Organophosphate (pesticides). However some of these tests are difficult to undertake without lab equipment and thus an awareness of what agricultural, industrial and mining activity has occurred in the area could be used in the first instance, rather than having recourse to testing.

3. Treatment technologies

Summary

Ground water will invariably be cleaner than surface water and will have less treatment requirements. Surface water sources in rural areas particularly, will probably need treatment to address high-suspended solids and subsequently to disinfect to kill off microorganisms. Removal of the suspended solids invariably present the greatest treatment challenge, and there is a need to choose technologies that will be sustainable in the medium to long term where required and over complex solutions should be avoided in general. For this reason the guidelines are written around the use of sedimentation and aluminum sulphate as a coagulant, as this is commonly available. There are a range of more complex and/or expensive solutions available on the market which are not dealt with here. Similarly the use of chlorine and slow sand filtration is explained here as these are the most appropriate low tech/cost solutions. Water supplies with chemical contamination, often found in industrialized areas are not dealt with here, as these tend to be much more complex to treat.

The basic principles of water treatment outlined below are applicable for all three scales of supply requirement; refugee/ displaced camp, village and household levels. Obviously, the scope and need for undertaking some tests, such as jar test, chlorine residual checks, roughing filter pilot studies etc, for treatment at household level is minimal, unlike requirements for centralised treatment systems. Non-the-less the principles for both testing and treatment are useful throughout. Which treatment technology or combination of technologies is used, also depends upon the type of water to be treated. The flow chart gives an indication of how different types of water could be treated, once the parameters mentioned in section 2 have been measured. As explained in the previous section, reduction of suspended solids, along with removal/disinfection of microbiological contamination are likely to be the main treatment concerns.



3.1 Suspended solids removal/reduction

This section is particularly applicable for surface water treatment. Most groundwater will have little or no suspended solids.

3.1.1 Treatment at intake

The intake (pump or gravity) is often the most neglected part of the treatment system, but it is very important, as allowing unnecessary debris and dirt into the system, means more treatment will be required downstream. Intakes should always be designed to reduce intake of debris and to strain out solid matter which would otherwise enter the treatment system, but flow control and cleaning can be problematic.

The creation of intake channels which do not face the main flow of a river can be effective in reducing the amount of suspended solids carried to any suction pipe inlet screen. Also the position of the intake relative to banks is important; fast flowing water carries more dirt and it is important to look for natural sedimentation basins within the river.

When the position of the intake has been chosen, seek to make it as efficient as possible whilst maintaining accessibility for maintenance operations. Twin lines have the advantage of allowing maintenance to be carried out, whilst abstraction rates are maintained in the other pipe and a second pipe can be added later where a treatment system is likely to be in existence for more than a few months. With careful planning of pumping lines and valve positions, suction pipe intake assemblies can be “backwashed” in position with selected washwater.

Fabrics wrapped around suction pipe screens and custom-made perforated pipes or drums can all have an application in maintaining good physical raw water quality and their length and thus their flow capacity can be adjusted to suit local conditions. Specifically the intake can be upgraded by using intake structures such as an oil drum or plastic drum (Oxfam code FPD), drilled with holes to act as a large strainer. Gabions constructed out of coarse gravel will also protect intakes from excessive suspended solids. Also simple measures such as positioning a pump intake strainer about 0.5m below the water surface (to avoid algae growth), but above the river/lake bed (to avoid drawing up sediments on the bottom) will have significant impact.

When time permits, the construction of sand filled intake galleries adjacent to sumps will provide better cleaning, although care must be taken in construction otherwise they will be prone to excessive blockages. If raw water quality is such that, even with the use of primary sedimentation tanks, treatment is being compromised due to high levels of physical contamination, consideration should be given to river bed or bankside filtration.

There are many different types of filtration/infiltration “intakes” and even more names given to them, but basically the aim is to obtain a raw water which has been “filtered” as it seeps through granular soil or selected fill. Fast flowing rivers tend to have sands and gravel deposits along their banks and excavation of a suitably long trench in the bank can provide access to a suitable supply of raw water which has been considerably improved by the riverbank filtration. This method is particularly recommended when algae is a problem. However, ponds, lakes and very slow rivers are more likely to have silts and clays as the local soil strata and, in this case, it may be necessary to construct a filter drain using imported materials. The surrounding riverbed itself becomes a biological filter that destroys bacteria and reduces the level of ammonia and iron that may be present. Water moving over this bed helps to clean it, helped by any fish present which will feed on these sediments.

3.1.2 Sedimentation

Sedimentation is the simplest form of water treatment of all and by allowing water to stand for a long enough period of time, improvements will be achieved with physical impurities settling (sedimenting) out and by pathogens dying off during water storage (standing). However, in some cases it can be rather slow to achieve sedimentation without flocculants to assist and very slow for pathogens to die off (requiring several days-weeks), designing a treatment system solely on this process of sedimentation and storage could result in a very high requirement for storage tanks and vessels. As a consequence, sedimentation is usually used as one stage in the treatment process, either for sedimentation of coarse solids or of flocs after coagulation/flocculation (see section 3.1.3).

Simple settling tests conducted in jars can give guidance on the amount of retention time required for any particular raw water, though these rather crude results should be verified on a full scale plant in practice. It is suggested that if suspended solids take more than 6 - 8 hours to settle out such that supernatant water (clear water on top) is less than 5NTU, then the process needs to be assisted, either by adding a roughing filtration or coagulation/flocculation treatment stage. At a water treatment plant level, this suggested time for adequate sedimentation should be considered in the light of overall system design and tank costs/availability, while at a family level the number of water vessels people have access to would be the determining factor.

While technical books exist for design of sedimentation tanks, these are often based upon use of purpose built tanks, often rectangular in shape with internal features to lend themselves to more efficient sedimentation. As these are not used by Oxfam either at bulk treatment or family level, it is not considered appropriate to go into the design theory for sedimentation tanks here, which is based upon these rectangular tanks. Inlet and outlet arrangements to Oxfam tanks used for sedimentation should be considered carefully to minimise the disturbance of sediment that builds up in these tanks between cleaning operations, otherwise treatment will be less efficient.

3.1.3 Coagulation and flocculation

Where excessive suspended solids in the form of colloids or organic matter, are present in water that cannot be easily removed by straining, or sedimentation, then the use of chemicals to assist in coagulation and flocculation will be required. Colloids can be thought of as suspensions of fine particles in the water which produce a cloudy or turbid appearance. The fine particles carry an electrical charge and exhibit a mutual repulsion which makes them difficult to remove by simple sedimentation or filtration. Coagulants act to saturate the particles with ions of opposite charge whilst reacting with natural hardness in the water to create flocs which trap the fine particles and aggregate. The aggregated flocs are then able to be removed by sedimentation and/or filtration. It should be noted that while flocculants do assist in the removal of pathogens which "cling" to particles of dirt, they do not kill them, i.e. they do not act as a disinfectant.

The most commonly used coagulant in developing countries is aluminum sulphate, known as alum, which can often be found in local markets in the form of crystals. While Oxfam uses powdered aluminum sulphate, other relief agencies use coagulants such as ferric chloride and ferric sulphate, which while being stronger coagulants, do present problems with airfreight and are less well understood by local operatives.

Aluminum sulphate (alum)

Aluminum sulphate (code FAS - common names Alum or Sulphate of Alumina) can be obtained in liquid or granulated forms and is commonly used as a coagulant. The granular form (chemical formula - Al2 (SO4)3.n H2O with n typically between 14-18) is most commonly used by Oxfam because it is relatively easy to freight (as it is not classified as a hazardous chemical), simple to transport by land in sacks and is widely available in all but the remotest areas of the world. It can be added to water and shaken or stirred vigorously to produce a solution which is suitable for dosing into the raw water in treatment processes. It does, however, have some detrimental health effects when used in the long term and its prolonged use is not recommended.

Aluminum sulphate coagulates best in a pH range between 6.5 and 7.5 as its solubility depends on the pH of the raw water and is lower outside this range. pH adjustment can be made to improve coagulation. The addition of acid, usually sulphuric, would be required to reduce the pH, while the addition of lime or soda ash will increase the pH. Aluminum ions combine with hydroxide ions during flocculation, and the addition of alum decreases the pH of the water. The addition of lime (an alkaline) will increase the pH and is useful to keep the pH within the optimum range.

The dose of aluminum sulphate required for coagulation of any surface water will vary, but will probably be in the range of 25 - 150mg/litre or 25 - 150g/m^3 (this is the weight of alum, of which only 25% of this weight is aluminum sulphate, the rest is water). The correct dose of alum will flocculate suspended solids in the water together into large "fluffy" lumps. These will then be heavy enough to settle out the water naturally within an hour or two. The settled water at the top should then be very clear, i.e. <5 NTU to permit effective chlorination.

Under or over dosing can result in inefficient flocculation and lead to aluminium residuals in the product water which exceed current WHO quality recommendations (WHO recommend aluminium <0.2 mg/l). For this reason and to ensure the use of an economical dose, it is normal practice to carry out a series of jar tests to determine the optimum dose. A simplified version of this test has been designed for Oxfam work in the field, where the normal "laboratory" support will not be available.

Determining the Dose - Jar Test

The purpose of the jar test is to determine the correct dosing concentration for an individual application where effective flocculation is employed. Pouring a bucketful of alum solution into a tank of water and stirring by hand is not "effective flocculation" but is sometimes required in extreme emergencies. This will almost certainly lead to excessive alum residuals in the product water, although they should not form major threats to community health in the short term. Every water treatment application is different in terms of raw water quality, hydraulic conditions and even

coagulant batch properties. Optimum conditions for good flocculation are determined not only by the optimum dose of coagulant, but also by the physical conditions of coagulant dosing. Jar tests should be conducted using a ***1%*** alum solution and the test is covered in detail in the Oxfam coagulation and disinfection manual.

Adding Alum to Water

For the aluminum sulphate to work properly and make the water clear, it needs to mix with the water rapidly. A short time after it mixes with the water it loses a lot of its effectiveness, so it is very important it is mixed with all the water.

The best way to do this is to mix the aluminum sulphate powder with a small amount of water to make a 10% solution, and then to add this solution to the water as it enters the tank. This is done as follows;

- To allow measurement by volume to be interpreted as a weight:1 litre of granular alum weighs 1100 grams. A baseline alum solution concentration is made as follows;

- A 10% alum solution is formed by dissolving 100 grams of granular alum into 1 litre of clean water (mix in less than 1 litre then make up to the final volume). This solution will be referred to as a 10% Oxfam Alum Solution.

- 10% Oxfam Alum Solution = 100,000 mg/1 (100,000ppm) Alum Solution

After the aluminum sulphate solution has mixed with the water, there needs to be a period of gentle stirring and mixing of the water in the tank to allow the aluminum sulphate to act on all the water. During this period, all the small particles of dirt (which remain in suspension or would sink very slowly) in the water are drawn towards the precipitate of aluminum hydroxide sulphate particles, to make bigger particles of floc, which will sink more rapidly. Eventually, these will form sediment in the bottom of the tank.

When aluminum sulphate is used for coagulation/flocculation it is important to occasionally test product water to ensure that there is not an excessive aluminum carry over caused by too high doses of aluminum sulphate or floc carry over. In both cases jar tests will help determine the optimum usage of aluminum sulphate and sedimentation times, but spot checks of the product water are important. Aluminum presence can be checked by use of a simple comparator (included in the Oxfam code FMT kit).

3.1.4 Roughing filtration – upflow prefilters

Upflow prefilters can be used to reduce the turbidity (suspended solids) levels in raw water to ease later treatment problems. A 1.0-1.2m deep bed of gravel media can reduce the influent turbidity by up to 75%, except where problems of difficult colloidal turbidity are experienced. The use of roughing filters will allow a much greater control over flow rates and cleaning regimes than can be achieved from treatment at pump intakes. This part of the process becomes much more critical when finer particles are being removed from the water.

Roughing filters are often built in tanks with a number in series (each tank being a stage), using progressively less coarse media in each tank. Raw water quality will determine how many stages, i.e. how many roughing filter tanks will be required. The more stages used (usually no more than three) the greater the cleaning effect on the water. If the water is fairly clean, a single stage filter, or one with three different sized media layers in one tank may suffice. However pilot plant studies run on a model scale will give the best results for design of the system and these trials should also take into account seasonal variations in water quality. As a guide, roughing filters should aim to produce water

that is <NTU20 (max) if water is then being passed through SSF (slow sand filter) or <NTU5 (max) if it is to be disinfected with chlorine.

Typical gradings for 40mm, 20mm and 10, nominal single-sized aggregate are shown in the following table:

Standard Sieve Size mm	Percentage by Weight Passing Standard Sieves for Nominal Single-size Aggregate		
	Coarse 40mm	Medium 20mm	Fine 10mm
50	100	-	-
37.5	85-100	100	-
20	0-25	85-100	-
14	-	-	100
10	0-5	0-25	85-100
5	-	0-5	0-25
2.36	-	-	0-5

A roughing filter based upon a multi (3) layer in 1 tank construction might look like this;

Grading	Depth of layer
Coarse	600mm
Medium	300mm
Fine	300mm

With the coarsest layer on the bottom for upflow prefilters. If poor raw water quality requires the construction of a three stage (i.e. three tank) system, then the tanks would be constructed in series using the same media size range, starting with the coarse media tank upstream.

Guidance on how many filters may be required can be drawn from the following information ***but will always be determined by the actual raw water characteristics****:* (It is assumed that they will be built in Oxfam T11 tanks).

The throughput of upflow prefilters is determined by applying a loading typically in the range 0.6 - 1.0m^3/m^2 of filter area/hour but 0.6m^3/m^2/hr has been shown to be the most efficient.

i.e. Throughput = Plan Area of T11 tank (1.3 x 1.3 x 3.142) x Loading x 1000 litres/hour.

As a guide, a roughing filter built of 3 layers in one tank has a % removal efficiency of 85% at 0.3 m/hr and 75% at 0.6m/hr. 3 roughing filters in series have a % removal efficiency of 87 - 92% when operated at 0.3 - 0.6m/hr (all for turbidity range 30-500 NTU). Thus for example, this might suggest that if raw water was NTU 50 and it was intended to chlorinate it, then 3 roughing filters in series would bring the NTU level down to about NTU5, which would be acceptable. If however the raw water was NTU80 and it was intended to pass water into a slow sand filter, then 1 multi layer roughing filter would bring the NTU level down to about NTU20, which would be acceptable.

Typical Performance of a 3 No, T11 Tank Series:

Influent UPF 1 =	400 NTU	(Raw Water)
Effluent UPF 1 =	120 NTU	(Influent UPF 2)
Effluent UPF 2 =	36 NTU	(Influent UPF 3)
Effluent UPF 3 =	12 NTU	(Further treatment applied)

However the use of roughing filters that require reasonably graded and sized gravel would take some time to build and are suitable for longer term use. For this reason the use of coagulants is recommended for the first phase, as they can reduce suspended solids more quickly and require less tanks.

3.2 Microbiological improvements

3.2.1 Disinfection

Dirty and polluted water can contain many harmful organisms. The disease causing organisms (pathogens) include bacteria, bacterial spores, viruses, protozoa and helminthes. These can cause diseases like cholera, bacillary dysentery, typhoid, infectious hepatitis and diarrhea. Disinfection of water aims to kill these pathogens without leaving any harmful chemical substances in the water.

Chemical disinfectants for water should have the following attributes:

- Destroy all pathogens present in the water within an acceptable amount of time.
- Be able to perform within the range of temperatures and physical conditions encountered.
- Disinfect without leaving any harmful substances in the water.
- Permit simple and quick measurement of strength and concentration.
- Leave sufficient active residual concentration as a safeguard against post treatment contamination.
- Ready and dependable availability at a reasonable cost.

Water treatments such as sedimentation and filtration can significantly reduce the number of pathogens in water. Chlorine is used to kill those remaining.

Chlorine

Chlorine is the chemical most widely used as it fulfills most of the above criteria for disinfection and is often widely available in one form or another (see section below). Under the right conditions chlorine will kill all viruses and bacteria, but some species of protozoa and helminthes are resistant to chlorine. Protozoa and helminthes are difficult to detect directly, but where these are thought be a risk, it may be necessary to resort to use of Membrane filters to strain out these organisms (the smallest of these are Giardia cysts at 7-10microns, while cryptosporidium oocysts are 4-6 microns). However though these are able to produce a high quality water, they will not provide much water quantity for a low capital investment and thus the cost of purchasing these may not be warranted where financial resources are limited.

How chlorine works.

The precise way in which chlorine kills viruses and bacteria is not known. It is believed that the compounds formed when chlorine is added to water, interfere with the chemical processes that are necessary for the survival of the viruses and bacteria. When a suitable chlorine compound is added to water, only a part of it is available for killing viruses and bacteria. This part is called "Free Available" or "Available" Chlorine (AC). Only small amounts of chlorine are required to disinfect polluted water.

After it has been added the active chlorine needs a certain amount of time to kill the viruses and bacteria in the water. This is called the "contact time" and is normally a minimum of 30 minutes for neutral pH waters. However, the length of contact time required for the active chlorine to be fully effective depends upon many factors of which the most important are pH and water temperature. A higher water temperature will enable the chlorine to work faster. Water standing in an open bucket will loose the taste and smell of chlorine (and thus disinfection powers) after a few hours as it dissipates into the air.

Most raw water sources have a pH value within the range 6.5 - 8. As pH levels rise, the disinfecting properties of chlorine become weaker and at pH 9 there is very little disinfecting power. See Table 1 below.

Table 1
Contact time/chlorine residual required for complete disinfection at higher pH

pH	Required chlorine residual at 20°C (mg/l)	Contact time needed for effective disinfection (mins)
8.0	0.5	30
8.5	0.2	206.0
	0.5	82.5
	0.8	52.0
	1.0	41.0
	1.5	27.5
9.0	0.2	412.0
	0.5	165.0
	0.8	103.0
	1.0	82.0
	1.5	55.0

Contact time must never be less than 30 minutes.

If the water to be disinfected contains a lot of suspended solids and/or organic matter (i.e. is highly turbid), it will have a high chlorine demand. WHO guidelines recommend that turbidity is less than 1 NTU for chlorination to be effective in destroying all bacteria and viruses, though 5 NTU is a more achievable limit and will be adequate in most cases. It is, therefore, desirable to remove suspended solids as much as possible before the chlorination process begins. This will significantly reduce the amount of chlorine needed and improve its efficiency as a disinfectant.

If iron and manganese are present in the water to be disinfected, a substantial amount of chlorine may combine with them to form compounds, which are insoluble in water. It is, therefore, beneficial to remove the iron and manganese. This may not always be possible, although simple aeration systems may be appropriate.

If too much chlorine is added to the water and the residual is too high, the water will have an unpleasant taste and smell, and consumers will prefer other sources which may be more polluted. Bad tasting water to one person may be acceptable to someone else and judgment of this is quite subjective. Normally when the free chlorine residual is higher than 0.6 mg/l most people will find the taste unpleasant, and will try to find an alternative.

Another problem in emergency situations is the use of dirty water containers. From time to time, once per week or once per month, extra chlorine should be added to the water so that there is a residual of up to 1 mg/l, to help deal with contamination that may build up in these containers, though this will have to be done in consultation with the community.

Types of chlorine

Chlorine is DANGEROUS. The safety rules concerning its handling must always be followed.

Gas and chlorine dioxide

Chlorine gas and chlorine dioxide are widely used in water treatment in Europe. However, the handling and transport of them is considered too hazardous for the sorts of projects Oxfam or its partners are likely to be involved in.

Calcium Hypochlorite - $Ca(OCl)_2$
Calcium hypochlorite, also widely known as bleaching powder or chlorinated lime, comes as powder containing approximately 33% available chlorine. It is stored in corrosion resistant containers. Once the container is opened, the powder quickly loses its strength. This can be very significant e.g. about 5% in 40 days if the container is opened for as little as 10 minutes per day, or approximately 20% if left open for the whole period.

The powder is not added directly to the water to be disinfected. The usual method is to make a solution of 1% available chlorine and add this to the water (see Table 2 below).

In making up these solutions of bleaching powder, it is advisable that the strength does not exceed 5% available chlorine. At this level of concentration a lot of chlorine can be lost as it is absorbed by the sediment. The most stable solution is 1% available chlorine. Solutions of chlorine are more prone to loss of strength than bleaching powder. Sunlight and high temperatures can speed the amount of active chlorine lost. To minimize such losses, the solution should be stored in a dark dry place and at the lowest possible temperature. The solution should be stored in dark corrosion resistant containers (glass, plastic, wood, ceramic) which must be securely closed.

More stable chlorine compounds are available on the market. They are more expensive to buy but because they last longer in the store, can prove to be more economical in the long run. High Test Hypochlorite (HTH) is one such stabilised form of Calcium Hypochlorite (Oxfam code FCH). It contains between 60 - 70% available chlorine and with suitable storage will maintain its initial strength with little loss. It is available in tablet or granular form. Other prepared solutions include ICI Tropical bleach - 34% available chlorine and Stabochlor - 25%.

Sodium Hypochlorite (NaOCl)
Sodium Hypochlorite is generally available as a solution commonly known as bleach, though it is however a poor substitute for Calcium Hypochlorite. Typical available chlorine contents range from 1-5% but can be as high as 18%. Before using these solutions the available chlorine content should be known. The solutions become less stable as the chlorine content rises.

Buying solutions of sodium hypochlorite is not economic for large scale use, as the transport costs are high. This results from the volume and weight to be transported. It is far better to buy powdered forms of chlorine and prepare solutions for addition to the water on site.

Slow Dissolving Trichloroisocyanuric Acid
This form of chlorine is used extensively to disinfect swimming pools. The chlorine, which comes in 200g tablets, is supplied by Oxfam as part of its emergency water supply packs (Oxfam code FCT). This form of chlorine is relatively stable and if stored in non-humid conditions at temperatures below 25^{o}C, can retain its full strength for two years. Oxfam supplies these tablets with a small plastic basket which floats inside the reservoir or tank. The compound dissolves very slowly in water and so it is suitable for disinfecting drinking water in wells or where a slow chlorine release is required. It is recommended that this form of chlorine is not used in drinking water supplies for more than three months in one year and not dosed at more than 10mg/l. It should be noted that the health risks associated with prolonged use of the tablets are much less than the risk ensuing from drinking non-disinfected water. Recently Oxfam has started stocking 350mg tablets, containing 136mg of Sodium dichloroisocyanurate, which will provide approximately 3ppm available chlorine when used in 28 litres of water. These are intended for distribution to families, particularly in flood situations, where by affected people will have to make their own arrangements for water treatment.

Determining the dose of chlorine.

When using chlorine to disinfect drinking water the aim is to kill off all the viruses and bacteria and then to leave a small amount of active chlorine in the water. This remaining chlorine is called the

"residual chlorine". The residual chlorine is desirable as it can disinfect further contamination of the water once it has been collected, e.g. from dirty water containers. It is desirable to have a residual free chlorine level of 0.2-0.5 milligrams per litre (mg/l). This can be measured quite simply (see section below).

The chlorine demand of water will vary greatly from one location to another. It is, therefore, important that the person responsible for the chlorination process is able to calculate the actual chlorine demand of the water to be treated.

This is a simple process of trial and retrial. Specific quantities of a chlorine solution can be added to litre samples of the water to be treated, e.g. sufficient to give 3, 4 or 5mg/l. The residual chlorine can then be tested after a minimum of 30 minutes. The chlorine demand can then be determined by deducting the residual from the amount of chlorine added.

Chlorine Demand = Known Dose - Residual Chlorine

When the chlorine demand has been calculated, the desired residual level can be added arithmetically to give the required chlorine dose per litre of water. E.g. chlorine demand = 3.5 mg/l, desired residual = 0.5 mg/l, chlorine dose = 4 mg/l. This figure is then used to calculate the amount of solution to be added to the volume of water to be treated.

For reference: When in water 1 mg/litre (mg/l) = 1 part per million (ppm).

It is very important that the free chlorine residual is measured as this indicates how effective the chlorination process has been. A very simple test involves the use of a kit designed for measuring the chlorine levels in swimming pools. It is called a pool test kit (Pool tester, Oxfam code FPO).

A sample of the water to be tested is placed in the comparator and a DPD No.1 tablet is dropped into it. The chlorine in the water reacts with the DPD tablet to give a level of coloration in the water. This colour is compared directly against the colour chart on the kit. The strength of colour then tells the operator the level of residual chlorine. To determine the total chlorine presence in water (free chlorine + used chlorine) a DPD No 3 tablet is added to the same compartment with the water tested with the DPD No 1 tablet and the reading taken accordingly. (The kit can also measure the pH of the water sample in a similar comparative manner using the phenol red tablet.)

During the dry season, the quality of the water in the rivers does not change by much, so that if the above procedures are followed, it should be possible to consistently produce water of good quality. During the rainy season, the quality of the water in the rivers can vary enormously from day to day. Extra chlorine will probably be required and this amount can only be determined by trial and error, and a better idea of the amounts needed will become apparent as the operators acquire experience of their individual systems.

Adding chlorine to water.

A solution of 1% available chlorine is recommended as the strength of solution to be prepared and it should be used as soon as possible after making it up. The following table (2) gives an approximate guide to producing 1% solutions from various chlorine compounds. The amount of chemical required will also be dependent upon age of the chemical used to make the solution, long periods of storage significantly weakening the chemical.

Table 2
Quantities of Chemical required to make
1 Litre of 1% Chlorine Solution

Source of Chlorine	Available Chlorine %	Quantity Required (g)*
Bleaching Powder	34	30 - 40
HTH	70	14
Tropical Bleach	34	25
Stabilised Bleach (Stabochlor)	25	40
Bleach	1% Solution	-------

* Where scales are not available, it may be necessary to make an estimate. 1 teaspoon is very approximately 14g, but this is not a very reliable measure

These quantities of chemicals should be added to 1 litre of water in the following way. The amount of chemical needed to make a 1% solution is placed into a suitable (preferably plastic) vessel and sufficient water is added to make a smooth cream, in the case of bleaching powder. It is best to use a wooden stirrer to break up the lumps. When all the lumps have been broken the cream should be diluted to the required amount using the remaining water and mixed thoroughly. The sediment should be allowed to settle out, and then the clarified liquid taken off to be used as the disinfecting agent in the water to be treated. For granular forms, such as: HTH, adding the required quantity to one litre of water and agitating will be sufficient to ensure good mixing.

Once the dose has been determined volumetric equivalents can be used to approximately measure the weight of chlorine and thus determine quantities to be used in operating the treatment process. Chlorine in HTH powder form has a density of about 800g/litre.

The 1% solution is used as the means of disinfecting larger quantities of water as shown in the table 3 below:

Table 3
Volume of chlorine solution to be added to different water volumes

Chlorine Dose Required	Volume of 1% Solution to be added to		
	10 litres	100 litres	1,000 litres
1 mg/l	1 ml	10 ml	100 ml
5 mg/l	5 ml	50 ml	500 ml
10 mg/l	10 ml	100 ml	1 litre

ml = millilitres

Using rough guide figures to give a 5mg/l dose of chlorine to a reservoir of 45,000 litres will require 22.5 litres of 1% solution.

Chlorination rules
- ***Treatment is important to get water to be less than 5NTU before chlorinating.***
- ***Check pH and temperature to help assess contact time.***
- ***Ensure minimum contact time is allowed before consumption.***
- ***Always test for residual chlorine levels.***
- ***Follow the storage guide for the particular chemical being used.***

3.2.3 Slow Sand Filtration

Before chlorination was introduced, slow sand filtration alone was shown to have significantly reduced the incidence of water-borne diseases in the UK. Probably no other single treatment process can simultaneously improve, to such an extent, the micro-biological, chemical and physical quality of water. It is simple, inexpensive and reliable and is still the most appropriate and favoured choice of treatment available.

Properly operated, a slow sand filter can remove 99% or more of the E.coli population (bacteria indicating the presence of faecal contamination) and even where water temperatures fall to 3^0C, a mean reduction of 97% E.coli and microbial pathogens can be maintained. However the sand filters need to mature for a period of a few weeks before the micro-biological action of the schumzdecke becomes fully active and during this time it is advisable to ***post*** chlorinate the water to ensure it is potable (chlorine will kill the schumzdecke if chlorine is added before filtration).

The slow sand filter is suitable for treating water of fairly reasonable quality, but which is low in turbidity (10-20 NTU), although peaks of 40-60 NTU have been accommodated for short periods of time. The slow sand gravity filter is essentially an open-topped box drained at the bottom and partly filled with a filtering medium (normally clean sand and a layer of stones or gravel). Raw water is admitted to the space above the sand and passes through the sand by gravity. Purification takes place during this downward passage and the treated water is discharged through the under-drains. The sand filter is not just a water-screening technique but the filter will develop a very active micro-biological treatment of the water. The filter will run for several weeks or more without cleaning. It may be useful to note that flows as low as $0.02m^3/m^2/hr$ could be used at night time when pumping may be difficult, in order to maintain the functioning of the Schumtzdecke.

3.3 pH adjustment

The coagulant most commonly used by Oxfam is aluminum sulphate powder (Oxfam code FAS), which though not a very strong coagulant, does have the advantage that it can be air freighted easily and is quite commonly available in different parts of the world. However, it does have quite a narrow pH range, operating best between pH 6.5 and 7.5 and outside these limits its efficiency goes down and hence more has to be used to compensate. This occurs as the solubility of aluminium precipitate increases dramatically outside this range, which means that where pH is too high or too low, a floc precipitate will be unable to form easily.

As the addition of (acidic) aluminium sulphate to water lowers the pH (by reacting with its natural alkalinity), there is a risk that water pH may fall outside the optimum range. Where water has insufficient alkalinity or buffering capacity, additional alkali must be provided, usually by the addition of Quick lime (CaO), as this will raise the pH of the water. As a guide, around 7 – 14kg of lime added to $95m^3$ of water will provide an appropriate level of pH adjustment, though clearly the actual amount should be determined as part of the jar tests.

3.4 Iron removal

Aeration can be used to reduce the iron content. Aeration will oxidise Ferrous Iron (II) to the insoluble Ferric Iron (III) and the precipitate can be removed with a bed of media. Some recent work has been undertaken on an uncomplicated aeration and filtration system, in which designs for iron removal plants may be simplified. Passage of water through a slotted pipe, produces a very limited spray of water, which is sufficiently aerated to oxidise the Iron, enabling it to be filtered out in a shallow bed of coarse sand.

Sand depths of 0.1m and 0.15m have been tested with 1.18mm sand (supported on a bed of 0.05m depth of 6mm gravel) and a depth of 0.2m depth tested with the 1.3mm sand. Iron containing groundwater (mean 7.5mg/l) was supplied to the filter beds. The 1.18mm sand beds consistently produced filtered water which met the WHO recommended levels of 0.3mg/l (i.e. 96% reduction), while the 1.3mm sand also produced water below the WHO limit, but less consistently.

These filters become clogged with time by trapped gases and iron precipitates but can be cleaned, on say a weekly basis or once flow is reduced (see table), by gently stirring the sand bed completely three times with a stick, taking care not to over stir as this will disturb the biofilm.

Typical flow rate m/hr

	Clean	Clogged
1.18mm sand	1.91	0.51
1.30mm sand	3.18	0.76

4. Application of treatment Processes

Summary

This section needs to be read in conjunction with section 3. which outlines the basic principles of various treatment processes, while this section concentrates on how these can be applied at various levels. Different situations demand different approaches. Perhaps the most appropriate categorisation of situation is along the lines of what scale treatment needs to be undertaken and whether the source of water is surface or groundwater. Thus a categorisation along the lines of the following has been adopted;

- Bulk water supply to large numbers of displaced people
- Village level facilities where people have not been displaced but face disruption of normal supplies
- Household level arrangements, where natural disasters, particularly floods mean people have to make their own arrangements.

4.1 Bulk water supply to displaced populations

Where larger groups of people are displaced either by conflict or by natural disaster and they are likely to stay in a particular location for periods in excess of a few weeks, there will be a need to establish and probably subsequently upgrade a centralised water treatment system. These situations are the ones in which the various Oxfam emergency water equipment packages are most appropriate to use. Reference should be made to the coagulation and disinfection manual for first phase responses and the water filtration manual for long term situations, which provide further details on their use and installation. Section 5 gives details of installation strategy and costs.

4.1.1 Suspended solids removal

Intake

Where pump intakes are required, the use of a plastic drum, (Oxfam code FPD), which can have holes drilled in it and can be used wrapped with filtration fabric, (Oxfam code FX). An oil drum could also be used for this purpose or lengths of slotted pipe, also wrapped with fabric will give considerable improvements in water quality. However all these arrangements will be prone to clogging quite quickly and thus they should be constructed in such a way that they can easily be pulled out and cleaned. To this end it is better to have a second set of filter fabric, which also acts as a backup, one set being in use while the other is being cleaned.

Coagulation/flocculation

A number of different methods can be used to dose coagulant, either into Oxfam tanks or onion tanks and these are listed below (A-C). However the following points apply whichever choice is made.

A check should be made on the aluminum carry over into the chlorinating tank, using the comparator provided in the Oxfam code FMT kit. If this is significant, then it may be worth reviewing the amount of aluminum being put into the raw water. Addition of lime, which will raise the water pH, before coagulation with aluminum sulphate may be desirable as alum lowers the pH of the water and may take the pH out of its optimum range.

The flocculated sludge is hazardous and arrangements need to be made for its proper disposal. In the early stages in the life of the system it may be adequate to dispose of it in a shallow pit dug nearby, though this will be less satisfactory in the long term if aquifer contamination is likely.

A) Coagulant dripped into water flow

The simplest but least effective way of introducing coagulant into a water supply is at the inlet where water flows into the tank. This will require the construction of a (wooden) tower on which barrels/drums can be positioned to drip the aluminum sulphate over the rim of the tank and into the inlet stream of water as it enters the tank. Where larger Oxfam tanks are used, this platform will have to be quite substantial to be high enough to reach above the lip of the tank and strong enough to take the weight of people. This will take some time to build and will generally not be suitable for use in urgent or fast changing situations.

The solution is put in a drum from which it drips into the water entering the tank at a measured rate. The speed at which the solution comes out of the container should be such that the container becomes empty at the same time that the tank is full. Typically a 200 litre plastic or metal oil drum with a tap (Oxfam code FPD or oil drum), is used. The inlet should be set up to achieve gentle stirring to facilitate the formation of flocs and is best achieved using a 1-2m length of flexible hose strapped horizontally to the side of the tank which produces a swirling motion in the tank water as it fills the tank.

Once the aluminum sulphate solution is mixed with the water in the tank, and the period of gentle stirring is finished, there then needs to be a further period during which the particles of dirt can settle. This time period can typically be 2 - 4 hours. After this period of settlement, the water should be clear enough to be emptied into the next tank (often a chlorinating tank). Outlet arrangements should be as for sedimentation tanks

B) Suction side dosing

There is a more basic way of adding coagulant which simply involves tapping the pump's suction lines with a small diameter pipe. The small diameter tapping uses the suction of the main pump to draw up coagulant solution from a container. However, there is the need to include a small on-line flow meter to measure the injection flow with valves on both the coagulant pipe and the main suction line. The coagulant pipe should join the underside of the main suction line to minimise the risk of entrapped air interfering with the injection process. The longer the suction line, the greater the risk of air bubbles occurring within the raw water flow. As before, the overall control of dosing can be achieved by varying coagulant pipe flow and coagulant solution concentration. However, the predictions of total throughput and maximum dosing rates for a given application are relatively uncertain before the system is run-in; it is recommended that proving trials are held before coagulant concentrations are fixed. The system requires fairly constant attention as the balance between flow rates tends to vary during operation.

C) MSR Doser pump

The use of accurate coagulation injections pumps operated by hydraulic (water) pressure can be worthwhile, especially for large scale and permanent piped water systems. The on-line MSR doser pump, which has been thoroughly tested by Oxfam, offers a means of injecting coagulant, typically in the form of a prepared alum solution, on a continuous stream basis. The doser does not require an individual power source, essentially being an injection pump "powered by the main flow". It sucks up coagulant solution from a storage container and injects it into the flow of raw water in the pipe system. The doser fixes onto the delivery pipework by means of standard threaded connectors. Bearing in mind the relatively low dosing rate required for coagulants, typically between 5 and 50 litres/hour, it is generally convenient to have a small doser mounted on a small diameter by-pass pipe but this does require a valve to balance flows.

The injection rate of the doser is able to be finely controlled by a threaded barrel adjuster. However, a specified pressure difference is required across the doser to allow the hydraulic actuation of the dosing piston and diaphragm. If the provision of a single pumping stage from water source to treatment works is a design requirement, this pressure difference must be achieved by siting the treatment work's sedimentation or header tanks at a raised level in relation to the doser. Full allowance must be made at the design stage for all head losses due to pipe friction and valves, as well as the space required to physically integrate the doser into the system. The associated "doser head loss" is dependent on the model used and is detailed in manufacturer's information.

The only routine maintenance required for the doser is a flush with clear water to clean internal valves and the diaphragm after use. Dose rates should be checked manually in the interests of maintaining efficient coagulation. There are two ways of adjusting the quantity of alum injected for a given throughput volume, firstly by adjusting the MSR doser within its injection rate performance limited and, secondly, by selecting a particular concentration of alum solution. It is advisable to fix an alum concentration based on an estimated injection rate from somewhere near the middle of the doser's performance range and to carry out fine tuning by adjusting the threaded barrel.

Plain and assisted Sedimentation

Either traditional Oxfam steel tanks with rubber liners or PVC Onion tanks can be used for this purpose. Care needs to be taken with inlet and out arrangements to minimise disturbance of sediment that builds up in these tanks between cleaning operations. To this end the inlet should be arranged to have an upturned elbow near to the bottom of the tank, which can later be upgraded to have a length of pipe tied the edge of tank, preferably at high level with slots/holes in, which will release water into the tank in a number of small streams, thereby creating less disturbance. The outlet should ideally be either in the form of an upturned elbow with length of straight pipe, at least 300mm above the base of the tank or alternatively a float can be tied to a length of flexible hose that draws off the cleanest water from the top of the tank. This will reduce outflow, but keep it constant.

Sedimentation using upflow clarifiers

While pressure filtration/straining systems of one variety or another are commonly available in package water treatment plants, Oxfam has rarely used these, as most of them are relatively complex and expensive, are dependent upon imported consumables and spares and lack robustness in environments in which there is often poor attention to backwashing and maintenance. However, Oxfam is aware of the limitations of its practice of dosing water with coagulants and subsequent plain sedimentation, due to lack of process control and product water quality, but wished to avoid use of specialist equipment found in package water treatment plants. Thus there was a need to develop a system that could improve water quality and quantity, and could complement the existing Oxfam approach by engineering simple treatment system into an Oxfam tank. This has led to the recent development and introduction of the upflow clarifier, which is essentially a sedimentation system.

A comparison is made between the Upflow clarifier and package water treatment plants (operating under pressure filtration) in the table below. ***Note: while the clarifier has been built and stocked, there may be certain situations that call for the use of package water treatment plants, but these are not dealt with in this manual.***

Upflow clarifier	**Package water treatment plants (e.g. membrane, pressure sand or other)*.**
Essentially a sedimentation system	Pressure filtration of one form or another
Requires erection of Oxfam T11 tank and installation of clarifier inside. ½ - 1 day to set up and operate	Quick installation, typically require coupling together units and pump. 1 – 6 hours to set up
Low head requirements, can operate by gravity from header/raw water tank	Requires several bar of head to operate, thus pump needed to operate filter directly
Backwash 1 – 5 times week. Very unlikely to clog	Backwash 8 – 10 times/day.
Simple cleaning by gravity, with occasional manual cleaning	Cleaning requiring use of pump, perhaps complicated
Can use any coagulant	May be coagulant specific
Primary function to remove suspended solids. Little capacity to remove chemicals such as heavy metals and pesticides	Some systems will be designed to also remove chemical contamination

If water contamination due to protozoa such as Giardia and cyrptospridium, which are chlorine resistant, is suspected then microfiltration membrane unit should be considered in addition to the clarifier.	Some systems will have capacity to deal with full range of pathogens.
Output 7-9m^3/hr (+)	Output varies, typically between 5-15m^3/hr
Low cost (£4,600 +), including the T11 tank which can be used elsewhere if required.	Varies considerably, but from £8,000 - £70,000

**** Though a wide range of types of these systems exist, typical characteristics /performance have been selected in order to broadly compare the systems. Some units will of course perform differently from that outlined above***

Roughing filter (prefilters)

A roughing filter kit has been developed, which can be built into Oxfam 11,000 litre tank, Oxfam code FRF. This is simply a corrugated steel mesh floor which is supported by 300mm columns and can take the weight of up to 1.2m deep layer of natural granular media. Additionally extra outlets and flanges are provided to allow installation of 4 No 3" outlets adjacent to each other, which are required for achieving fast wash out velocities for thorough filter cleaning. All standard 2.6 metre diameter Oxfam T11 tanks can be converted into roughing filters and may be constructed in series where multi stage prefiltration is required.

4.1.2 Microbiological improvement

Chlorine

Some more specialized forms of chlorine in tablet form may be appropriate to use, but both are quite specialized and expensive. Where slow dissolving Trichloroisocyanuric Acid tablets are used, a basket containing these should be placed near the inflow of the tank so that the incoming water flows over the tablets. This is the best way of ensuring good contact between the water and the chlorine. When using the 45m^3 Oxfam storage tank, initially use three tablets (four for the 70m^3, five for the 95m^3). The residual chlorine will need to be checked daily and the number of tablets adjusted accordingly. The tablets should last between 7-14 days. HTH tablets are also available to be used if required. They have the advantage of dissolving slowly in a water flow, but they are more expensive to use than HTH powder.

Slow sand filtration

This treatment process has been engineered to fit inside an Oxfam tank. The slow sand filtration (SSF) package requires the use of 1 No T95 Oxfam tanks (for raw water), 1 T70 Oxfam tanks (for the slow sand filters) and tank(s) for treated water. The fittings and filter fabric are provided in the filtration fittings kit (Oxfam code FF). The slow sand filter comprises a bed of clean, medium-coarse sand with a particle size of 0.3 - 0.4mm about 800mm in depth, supported on a bed of gravel or broken stone 225mm thick with a drainage point at the bottom for collecting the treated water. It should be noted that it can take 2-3 weeks to procure, wash, grade and install the locally procured sand for an Oxfam slow sand filter.

It is important that the flow through the filter should be controlled at a flow rate of 200 litres per square metre of filter surface per hour, which can be visualised as being equivalent to a downward velocity of 0.2m/hr. This will provide a total of 153m^3/24 hours from the 1 T70 tank used as a SSF. The operation and maintenance of slow sand filters is described in the Water Filtration equipment manual.

The finer the filter sand the more efficient will be its filtering action but the quicker it will clog and need servicing. If the rate of filtration is lower, i.e. 0.1m/hr rather than 0.2m/hr, less head difference is required to operate the filters and the time between cleaning can be increased. However less water will be produced and thus additional filters would be required to produce the same amount of water. Thus a balance must be sought between being able to produce less water with easier operational and

maintenance considerations or more water but at the inconvenience of greater operational and maintenance demands.

4.2 Village level facilities

This categorisation would normally apply to smaller “village size” groups of up to several hundred people, who may or many not be displaced from their normal living conditions. Where displacement occurs it is likely to be for a period of a few weeks or couple of months, i.e. relatively short periods of time in which the provision of assistance in likely to be relatively temporary and of low input compared to bulk water supply to camps. Where existing village water supplies are based upon simple hand pumps and which provide groundwater is usually microbiologically clean, flooding or other situations arise in which chlorination may be desirable if the wells themselves become contaminated or if general hygiene conditions are poor. If these populations are reliant on untreated surface water, consideration could be given to provision of smaller filtration systems. It may also be the case that village populations are forced to congregate on higher or safer ground during times of flood or other disaster, but in numbers which only require small scale treatment systems.

4.2.1 Suspended solids removal

Roughing filtration (prefilters)

The same principle of engineering the necessary components to construct a roughing filter has been undertaken in a metre diameter plastic bin, and this system is available through a company called Potapak which come complete with the necessary pipework and accessories for simple granular filtration. This can also be partially achieved using oil drums etc, but the quality improvements will be less satisfactory, but these may be worth having if it is better than what people would have otherwise. The recommended throughput for these is 0.4 – 1.0 m2/m3/hr and therefore they can produce 0.5 – 1.2 m3 of water per 24 hours, for raw waters between 10 – 100NTU, making them more suitable for village level water treatment. Clearly with this level of production, several units would be required where the population is much more than 100 people.

4.2.2 Microbiological improvement

Disinfection

Where tubewells, fitted with handpumps are available and still functioning, these are the most appropriate method of supplying water. However, though it may be desirable to provide a chlorine residual in the water, this is difficult to achieve prior to the water being pumped into water containers. Wide diameter dug wells can be chlorinated either by pouring in a very strong solution to superchlorinate the well, before pumping out, or to use pot chlorinators, in which chlorine powder is mixed with sand for slow dispersion into the water.

Tube well cleaning by chlorination can be achieved by removal of the handpump and pouring a dose of chlorine solution, which may be based upon HTH powder or bleaching powder (BP) if local procurement is undertaken, down the well. In the case of bleaching powder; this should be dry and powdery, not caked or showing any sign of clumping and smells strongly of chlorine.
Steps to chlorinate a well

1. Pump water out of the well for at least half an hour, longer if possible. This water should just be allowed to drain away well clear of the well. The water should be clear before pumping is stopped. If it is not still clear, keep pumping.
2. Clean the surrounding area, so that one can work in a clean environment.
3. Remove pump head and in case of Tara pump, the pump rod as well. The pump rods should be stored carefully (not allowed to lie on the ground).
4. Make up a 1% chlorine solution in a container from which pouring can be done easily, without spilling.

5. Pour this chlorine solution into the tube-well taking care not to spill or splash it.
6. In case of Tara pump, replace the pump rods.
8. Wait for one hour, letting the tube-well with the chlorine solution inside, sit undisturbed.
9. Pump out the water for at least half an hour or until the smell of chlorine is gone. Let this water drain away and don't let anybody use it especially for drinking or cooking.

Alternatively work undertaken in Bangladesh by Oxfam has enabled the development of a simple hand pump chlorinating system which is suitable for suction lift hand pumps and enables a residual to be maintained during water supply, unlike the method above which is intended for one off cleaning. This consists of providing a small reservoir for chlorine solution adjacent to the pump, probably set in the ground, from which the solution is drawn into the water as the pump suction action draws water from the well. However contact time can only be achieved during carriage of the water and storage in the dwelling.

Slow sand filtration

The Potapak system has also been developed to use the same sized plastic container as used for the roughing filter, to produce a slow sand filter, which has a capacity to produce 0.52 m^3/hr, i.e. 12.5m3 of water per day. This would be equivalent to 1,250 people if 10 litres of treated water were used by each person. Particular attention would have to be paid to pumping arrangements and to ensure that a constant flow is maintained through the system.

4.3 Household level arrangements

In situations such as floods, people are often forced to find their own means of treating water at a household level. While the appropriate technologies are outlined in detail in a booklet written in Bangladesh on water and sanitation responses to natural disaster situations, a brief outline of what has been used by Oxfam is mentioned below. In these cases the number of people affected can be so large and their dispersal over such large areas, often means that the best implementation strategy is to provide material assistance such that the household can make their own arrangements for water treatment. The provision of water containers with instructions written on the side for the use of chlorine, along with a supply of chlorine tablets has been found to be a simple yet strong combination for encouraging people to treat water effectively. On the other hand the introduction of new and complex water treatment solutions, while perhaps being “technically” better, if they are unfamiliar will invariably result in a lack of improvement in safer water being consumed by people.

4.3.1 Suspended solids removal

Intake/source

Where surface water is taken from turbid water sources, the simplest method for removing coarse solids is simply to strain water through cloth to remove the bulk of these. Where multiple layers are used, these can be graduated with the coarsest fabric on top, progressing to the finest on the bottom. Different coloured cloth would help distinguish which layer should be used uppermost. This will certainly aid other treatment processes and improve aesthetics of the water.

Sedimentation

Where households have an ample supply of water containers, then the use of sedimentation may be a very effective way of treating water. By having sufficient containers to allow the raw water in the water container to stand for 3-4 hours or settle overnight, then most solids should settle out and the top clean water can be transferred to another pot and the residue thrown away. This water should be reserved for drinking but as pathogen reduction will be incomplete, it would still require use of chlorine or boiling subsequently.

Coagulation/flocculation,

A crystallized form of alum is quite commonly available and used by people in many parts of the world. Crystals are typically ground down and slakes of powder put into the water. Local experience

will best guide how much to use, and a tendency to use excessive alum is unlikely as it will have both taste and economic costs, but it may be of concern in some areas. The main limiting factor here is likely to be money to buy the alum, physical access to markets during floods and also a possible lack of water containers in which to decant treated water into after coagulation has occurred. Water will still need to be disinfected, usually with chlorine after this stage has been completed. As a guide add one teaspoonful of alum to about 10 liters of raw water, stir to dissolve, stand for 30-45 minutes, take water from top, throw out the residue at the bottom.

More recently some companies have developed a sachet of chemicals, that combines a coagulant/flocculant with a disinfectant. This is a relatively costly way of offering up a two in one water treatment process and will likely require high amounts of chlorine in order to compensate for high demand because of the presence of suspended solids. While relative concentrations of coagulant and disinfectant can be varied according to customer specifications, non-the-less the quantity will be fixed and not take into account variations in raw water quality. To some extent this can be compensated for by using less or more than one full sachet. One particular product costs around £0-14 for a sachet, which treats 20 litres of water.

Roughing filtration

Crude straining of water through a gravel filter may yield good results, but is unlikely to be designed and maintained in the same way as a large scale water treatment plant and water quality will be correspondingly poorer. A particular difficulty will be in maintaining a constant throughput, which is desirable. However the use of clay pots, oil drums etc for containers could enable the building of household sized filters, though it is unlikely that these would be built and used by a community unfamiliar with them during an emergency or post emergency phase without intense support.

4.3.2 Microbiological improvement

Disinfection

Either chlorine tablets or bleaching powder can be used where available from the local market and dosed according to achieve a low level of chlorine taste after suitable contact time. However a number of issues need to be considered here and checked where possible and local advice given accordingly.

- Consider the use of the tablets/powder only for the period at which people are at greatest risk, i.e. if for treating flood water, then tablets/powder could be used when protected sources such as wells remain unusable or when surface water is particularly dirty during and immediately after heavy rains.
- Do people have the normal practice of using chlorine? If they don't then provision of instructions on chlorine packets would be necessary in conjunction with verbal information dissemination about use (often via health promotion teams). This would need follow up to check understanding and practical application.
- Do people maintain adequate contact time - this may be difficult if people don't have enough storage vessels?
- Is water of low enough turbidity?
- Is pH so high that it requires additional contact time?
- Is chlorine that is available on local market of good quality?- In some cases it has been found to have little on no strength.

Water can be treated with chlorine powder or tablets as follows;
Chlorine powder: 1/8 teaspoonful of bleaching powder (BP) for 10 litres of water
BP should be; dry, white, powdery not caked, smell strongly of chlorine and stored in closed container. Take one teaspoonful of BP, divide it into eight parts, make eight tiny packets. Put one packet into one pitcher (10 liter) of water and mix thoroughly. Allow at least 30 minutes contact time. Now this water is ready for use. Note: At the end of 30 minutes water must give a chlorine taste (trace). If no taste is found, dosing is to be increased.
Water purification tablet Oxfam code FPU.

Method: Take 1 tablet of strength 3 mg in 14 litres (Oxfam bucket) or 2.1mg in 20 litres (Large jerrycan) of water. Put the tablet into a pitcher or bucket containing 14 or 20 litres of water. Allow at least 30 minutes to mix these tablets into water. Then use it. If the strength of the tablet varies from above then the ratios should be adjusted accordingly.

Disinfection by sunlight (ultraviolet ray)

If chlorine is not available, the water could be disinfected by sunlight. This is achieved by transferring strained water to a number of white glass bottles or white glass jars and keeping it in direct sunlight for at least 5 hrs. Then use it after normal cooling overnight. This can be improved by painting one half of the bottle black and the filled bottle is lain with the black side facing down in the sun for five hours. This exposure to UV destroys over 95% of the pathogens in the water.

Boiling water

Where use of fuel is not likely to cost a family (often the women) too much money or time to collect fuel, or put an undue burden on the environment, boiling of water for at least 10 minutes will be very effective. (At a higher altitudes, where water boils at lower temperatures this may not be adequate.) Water must be brought to a rolling boil. Tests have shown that 5 minutes at a rolling boil is sufficient to kill cholera and Shigella. However, It is necessary to boil water for 20 minutes to ensure complete sterilization. Let the boiled water cool to normal temperature overnight.

Candle filter

Where these can be purchased in the local market cheaply (sometimes for as little as a few $s), these afford the benefits of a water treatment facility that requires no consumables, yet will last for many years if cleaned and looked after.

Slow sand filtration

Slow sand filtration at household level is likely to be less successful at pathogen elimination, both because selection of the correct sand grading and always having a constant flow through the filter which is essential to maintain the Schumtzdecke are not likely to be achieved. Thus while there will undoubtedly be improvements in physical quality of the water, it is likely that pathogens will remain, albeit on a reduced level. Claims about what these household slow sand filtration arrangements are able to achieve must be viewed with some care because of this.

5. Installation strategy (bulk water supply)

Summary

The examples given below are based upon a situation in which a water supply is required for the arrival of large numbers of displaced people in an area with an inadequate water supply, which necessitates the construction of a new or supplementary capacity. The strategy outlined below is a very loose guide as to what can and has been done to treat dirty surface water, based upon the use of Oxfam equipment. Doubtless, different situations will require modifications to this, or even a completely different approach.

The following example sets out a process for supplying a population of 20,000 in three phases. In the acute phase of an emergency, when it will take some time to build water treatment systems, it may only be possible to provide a limited quantity of water, in which case 9 litres/person/day would be acceptable for a short time (perhaps for first days or few weeks). As the situation stabilises and more capacity can be built, the amount of water can be increased to 15 litres/person/day. The required output will therefore increase from 180m^3/day to 300m^3/day. For the longer term phase, chemical demand can be reduced by using roughing filters and slow sand filters. The inclusion of costs for each phase is given to indicate the additional equipment cost necessary at each stage. Conversion of the Oxfam tanks from one treatment system to another enables these costs to be kept to a minimum. ***The length of phases, the quantities of water the systems can produce and the amounts of water actually required, are indicative only and should not be read as absolute, as these will depend upon the situation***.

5.1 Acute phase

(Assumed time frame 1 month, production 180m3/day, equivalent to 9l/person/day)

In order to deal with any suspended solids, a configuration of raw water tank (30m^3 onion tank or Oxfam tank), Upflow Clarifier (Oxfam T11 tank) and clear water/chlorination tanks tank (30m^3 onion tanks or Oxfam tanks) built in series would deal with most waters. Alternatively an aluminum sulphate dosing tank (Oxfam 70m^3 tank) could be used instead of the Upflow Clarifier. Work should also be undertaken on building a pump intake to minimize the amount of suspended solids coming into the system. Initially water would be pumped from the source directly into the Upflow raw water tank, but at a later stage a raw water tank should be introduced to allow both settlement of larger suspended solids and dosing with lime if required. Ideally water would flow under gravity through the rest of the system, so selection of a suitable site wit ground slope would be helpful.

The raw water would be pumped for three to six periods (depends on raw water storage tank volume) over a 24 hour period into the raw water tank, where it would be allowed to sediment, before flowing into the Upflow Clarifier, prior to which aluminum sulphate would be added. The actual volume of water produced by the Upflow Clarifier would be dependent upon the raw water, but a minimum of 180m3 over 24 hours should be possible. Finally this water would be released into the chlorination tanks. After chlorination it would be available for distribution. Thus the system works on a part batch, part continuos throughput basis. It is assumed that treated water will not be collected overnight, so storage is required for up to 50% of the produced water. Sloping ground permits optimum use of tank capacity and increases flow rates between tanks. Ideally inlet level of the lower tank will be below draw-off level of the higher tank. Space should be left for future upgrading and expansion of the system as required. It will be better to have two chlorination tanks so that one can be distributing water whilst the other is being chlorinated. Also if the ground is flat, the use of two T45s increases the effective capacity of the system because of the shallow tank depth, rather than using one T95.

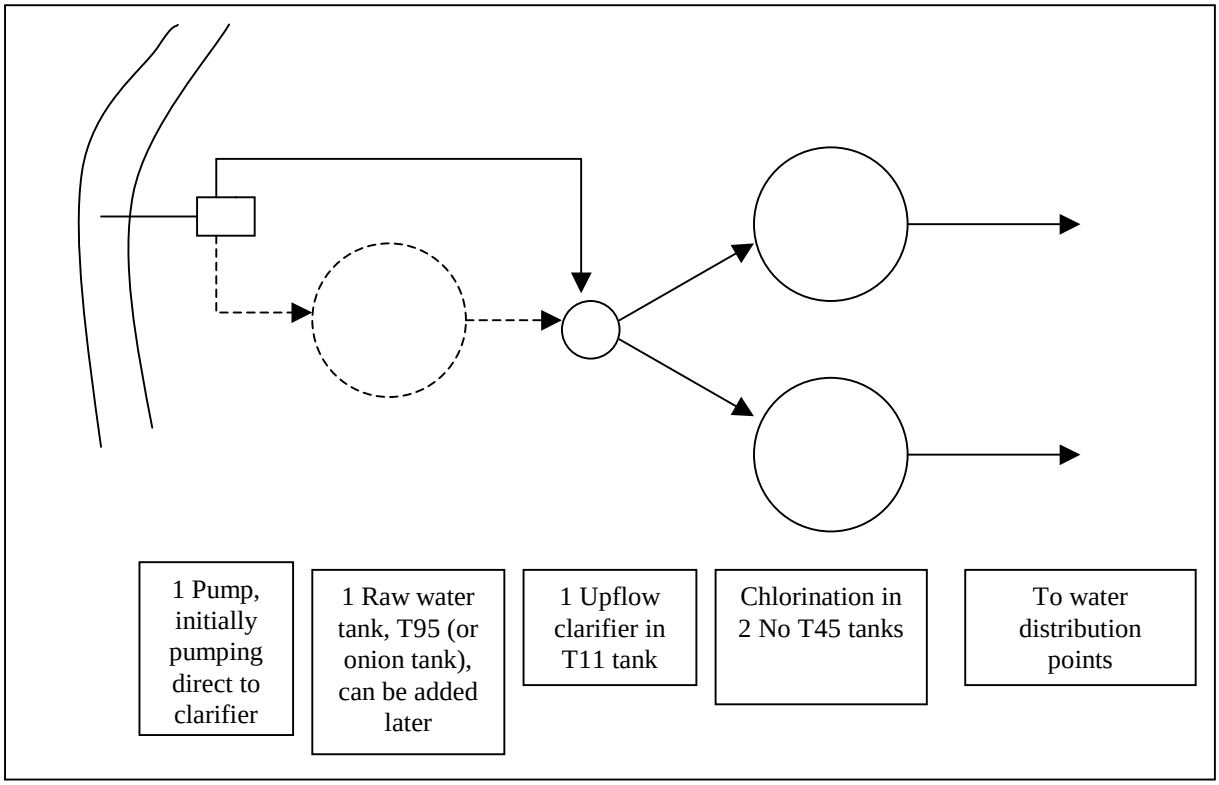


Figure 2 Acute Phase

This would produce: 7.5m^3/hr x 24 = 180m^3/24hrs
Assuming that;
- The system, works on a continuos basis and the Upflow Clarifier produces 7.5m^3/hr
- Total pumping time is about 6 hours, in 3 batches of 2 hours each.
- Tank level differences permit the system to work at peak flow under gravity.

The approx. 2000 costs for the Oxfam equipment are;

Cost (£)	Quantity	Oxfam kit
3,400	1	P4 pump*
3,000	1	T95 raw water tank
2,700	1	Upflow Clarifier kit
1,200	1	T11 for Upflow Clarifier
480	1	Alum dosing kit
320	1	Chlorine dosing kit
4,600	2	T45 chlorination and storage
400	1	TF tank fittings
16,100		Total phase I equipment

* a standby pump would normally be provided in addition.

5.2 Late emergency phase

Assumed time frame 1-6 months, production 300m3/day, equivalent to 15l/per/day

If it becomes apparent that the affected population will remain in their location for a longer period of time, then the ordering of further equipment may be appropriate to allow expansion of the system. This may be achieved most appropriately by doubling up the existing system to provide extra capacity and to ease the problems associated by nighttime operations by running the system for less time at night. More water will be supplied to people and the system could be operated for only 16 hours per day, recognising that 24-hour operation is difficult to manage for long periods. This would

mean that the Upflow Clarifiers would be operating on a batch process, which should not present any major problems. Additionally it would be advantageous to make improvements to the intake structure at this stage.

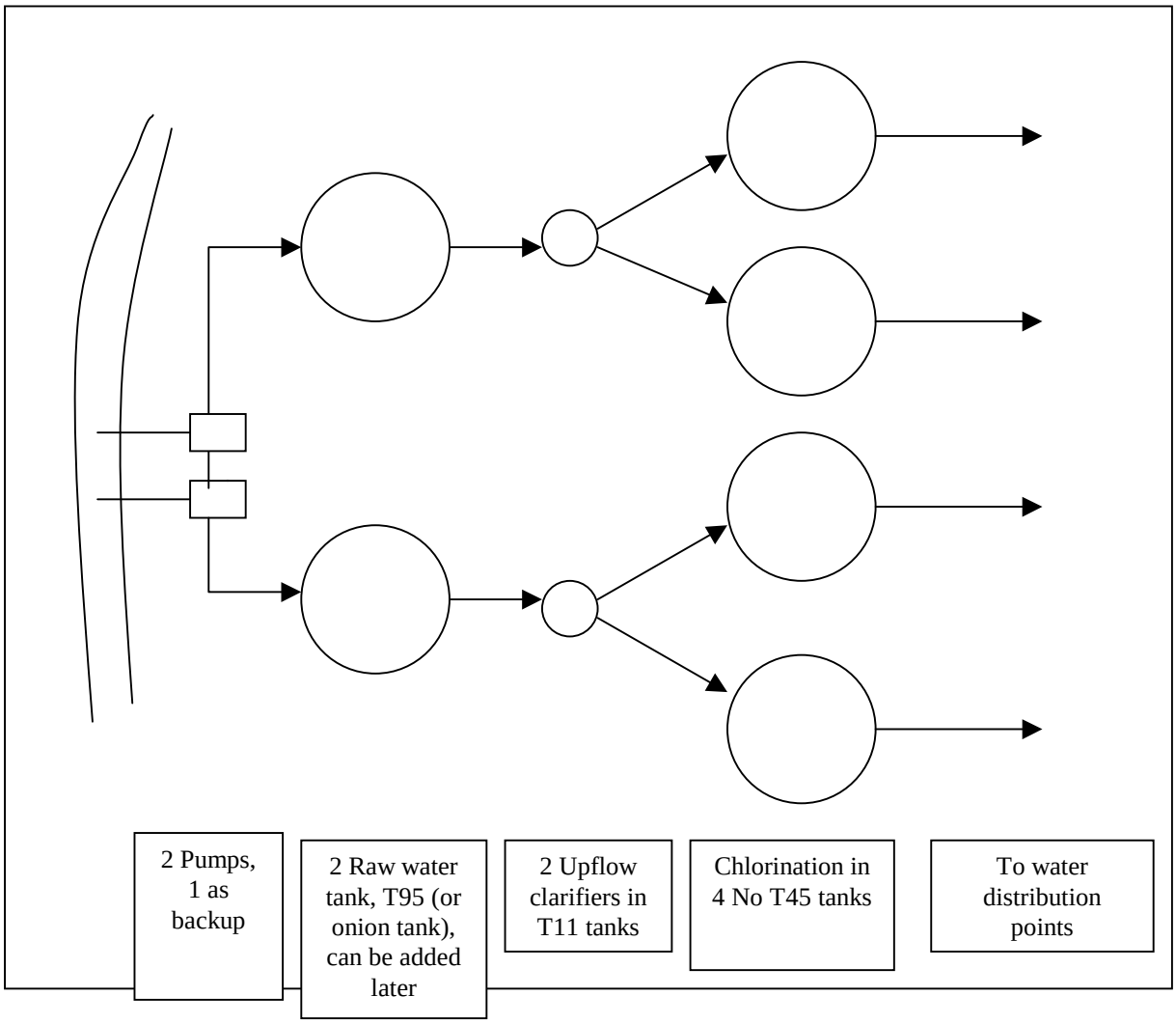


Figure 3 Late Emergency Phase

This would provide up to $60m^3$ x 5= $300m^3$/24hrs
Assuming that;
- The system, works on a batch basis and coagulation time is 6 hours
- Total pumping time is about 10 hours, in 5 batches of 2 hours each.
- Tank level differences permit draw down of the raw water tanks and coagulation tanks sufficient to remove $60m^3$ of water (remaining $10m^3$ is sludge).
- One coagulation tank will have three batches of water passing through by allowing settling out over night.

The 2000 costs for the Oxfam equipment are;

Cost (£)	**Quantity**	**Oxfam kit**
6,800	2	P4 pump*
6,000	2	T95 raw water tank
5,400	2	Upflow Clarifier kit
2,400	2	T11 for Upflow Clarifier
960	2	Alum dosing kit
640	2	Chlorine dosing kit
9,200	4	T45 chlorination and storage
800	2	TF tank fittings
32,200		Total phase I equipment

(including £16,100 - from phase I costs) * this includes one pump as standby

5.3 Post emergency phase

(Assumed time frame, post 6 months, production 306m3/day, equivalent to 15l/per/day, which would be supplied on a more sustainable basis)

In certain cases, particularly with refugee caseloads, it will be apparent that people the affected population will remain for a period of up to 6 months and sometimes beyond a year. While the construction of permanent systems may not be financially or politically desirable, it is worth considering whether there is a need to convert the temporary physico-chemical systems to temporary granular filtration systems or find alternatives sources, particularly groundwater. For the long term running of the water treatment systems, it is better for reasons of sustainability, reduction of dependence upon imported consumables and for health reasons, that the coagulation system is replaced by using roughing filters(s). Where possible the chlorination should be reduced or eliminated by using slow sand filters. However continued chlorination of the water may be desirable, even if slow sand filtration treatment is used, where population density is high or where excessive water related morbidity is occurring.

Thus by converting the function of the existing tanks and adding one extra tank, it is possible to re-configure the systems along the lines below. The raw water tanks are kept the same, the two Upflow Clarifiers would be converted into roughing filters with another two T11 tanks added, two T70 tanks would be have to be added to make slow sand filters, with the final tanks remain as before. The raw water quality would determine how many stages of roughing filter would need to be built, but the diagram shows a single multi-stage filter. The slow sand filters would need to be built between the T11 tanks converted from upflow clarifiers into roughing filters and the final tanks and thus sufficient space and height level difference would need to have been left during construction in phase I.

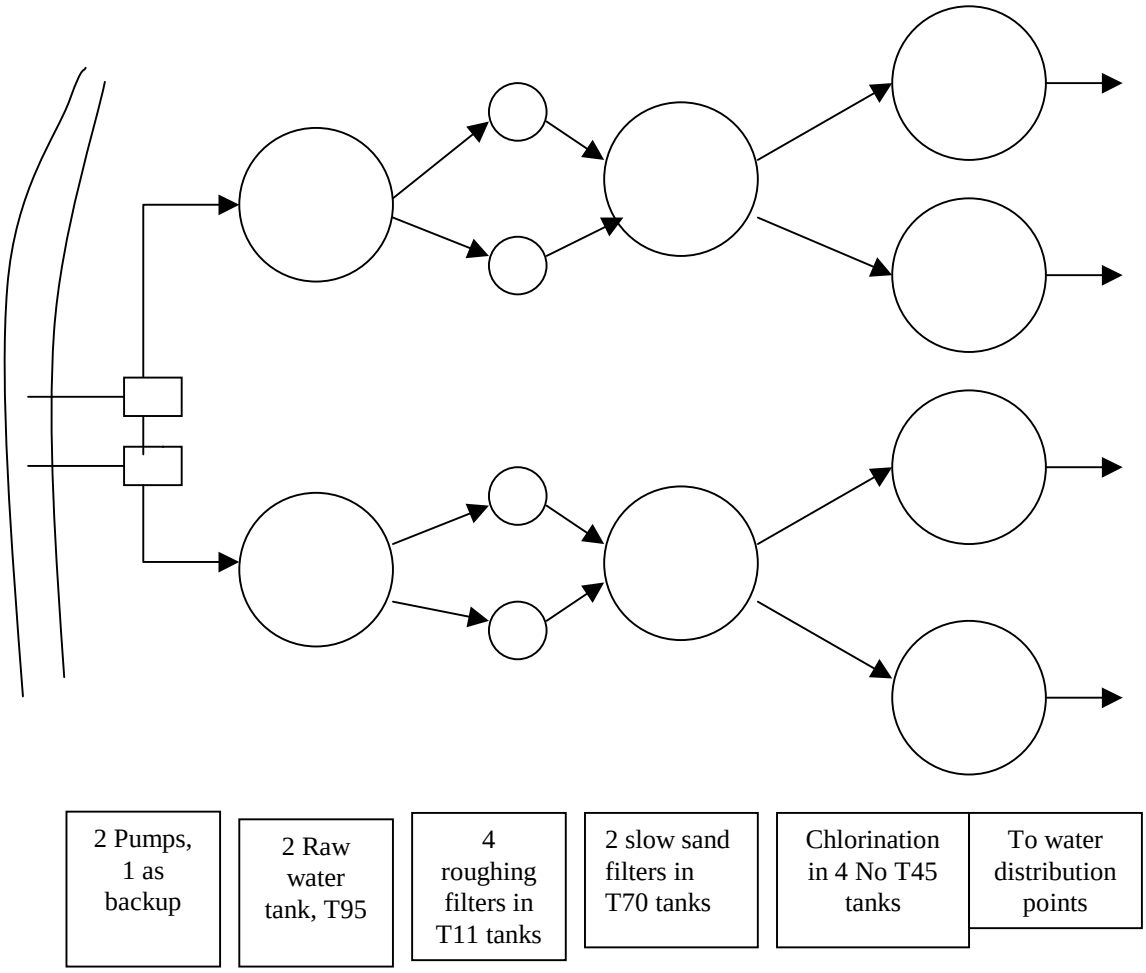


Figure 4 Post Emergency Phase

This would provide up to:
306m^3/24hrs
Assuming that;
- The raw water tanks are filled on a batch basis.
- The roughing filter and slow sand filters work on a constant throughput basis (SSFs and to a lesser extent RFs, will not function properly if a constant throughput is not maintained).
- Total pumping time is about 8 hours, in 4 batches of about 2 hours each.
- Tank level differences permit draw down of the raw water tank sufficient to remove 70m^3 of water.
- The roughing filters would be working at a throughput of 0.6m/hr and operating on single stage basis. (However it should be noted that the number of stages of roughing filters required depends upon the raw water quality and tests should be undertaken to determine the optimum number of stages required - see section 3.4.)
- The slow sand filters would be operating at 0.2m/hr.

The 2000 costs for the Oxfam equipment are;

Cost (£)	**Quantity**	**Oxfam kit**
6,800	2	P4 pump*
6,000	2	T95 raw water tank
4,800	4	T11 roughing filter tanks
7,200	4	FRF, roughing filter fittings
5,500	2	T70 slow sand filter tanks
4,650	1	FF slow sand filter fittings
9,200	4	T45 chlorination and storage
800	2	TF tank fittings
44,950		Total phase III equipment

(including £16,100 - from phase I costs and £16,100 - from phase II costs

* this includes one pump as standby

6. Operation/Management (bulk water supply)

Summary

This section details some of the main concerns that would be encountered in management, operation and maintenance of a system.

6.1 Operation

Care should be taken to ensure that there is good co-ordination between pumping regimes and dosing of chemicals. Every time there is a need to pump water from the source the pump operator needs to inform the person responsible for chemical dosing, so that they can add the chemicals at the correct time. Every time the raw water tank has been emptied into the chlorination tank the pump operator should be notified so that the raw water tanks can be refilled, in order to maximise the output of the system. A pumping/tank emptying schedule should be drawn up, specifying time for all operations to be performed and who performs them. Operators should fill out forms to record actual performance - see form 3 in Annex 3. Slow sand filters and roughing filters need to be operating at the optimum throughput but should not exceed the operating maximum throughput. SSF should be operated at around $0.2m^3/m^2/hr$ though where required for maintenance purposes they can go down as low as $0.02m^3/m^2/hr$. If they are turned off the schmuztdecke may "die off" and then will need to be reestablished. Roughing filters run at an optimum of $0.6m^3/m^2/hr$ but it would not be recommended to go above $1m^3/m^2/hr$ as water quality falls off considerably. These can be turned off for maintenance without too many problems being encountered.

6.2 Monitoring

Various parameters should be measured on a regular basis, to:

- Record whether the operation and treatment systems are working properly.
- Reveal a need to adjust treatment according to changes in raw water quality.
- Assist stock control.

Turbidity, pH, faecal coliforms, alum carry over, chlorine residual, should all be measured and a standard form for doing so is included in Annex 3, form 2. (Use FMT kit)

Daily records of the amounts of water the system has produced, along with the quantities of chemicals and fuel used per day should also be kept. These records should be passed on to supervisors, or the engineer in charge so that they also know what is happening in the system. This allows planning ahead so that chemicals, fuel etc. can be ordered to keep in stock. These records will also reveal problems with the system, as a set of good records can often help to quickly identify the problem, see Annex 3, form 3.

6.3 Maintenance

Cleanliness and tidiness are both important for this work.

First: This helps to make the work place safer.

Second: The purpose of the treatment system is to provide safe drinking water. If the site is dirty, it is possible that recontamination of the water can occur.

Third: It gives operators a pride in their place of work and a sense of more responsibility towards their work.

Fourth: It makes the working environment safer.

Use and safe handling of chemicals

The bags or containers of chemicals should be kept in a secure store. They should be protected from rain, damp and sun, and should be stored off the ground on wooden pallets or similar. Poorly stored chemicals can spoil and be of little or no use. Chemicals are expensive and not easily disposed of or

replaced once spoiled. Where chemicals are to be purchased in country the quality of these should be checked to ensure that what is being purchased is of the specified and required quantity.

Chemicals should be treated with care. Aluminum sulphate and, especially chlorine, should only be used in well ventilated areas. Avoid breathing in the fumes/powder of the chemicals.

Chlorine especially can be very dangerous. Once it becomes wet, or is mixed with water, it becomes caustic. When mixing with water, add small quantities of powder at a time, and stir carefully to avoid splashing. Rubber gloves should be worn when working with chlorine to protect hands. (This equipment is available in the Oxfam kit code XSO.)

If chlorine solution should splash on your skin or hands, wash it off immediately with plenty of water. If the solution should splash in your eyes, rinse them repeatedly with clean water, and see a doctor as soon as possible. Aluminum sulphate (alum) solution is highly corrosive. It will slowly dissolve metal drums.

Tank cleaning

The process of sedimentation, means that dirt is separated from the water and left in the bottom of the tank when the clean water is emptied into chlorination tanks. The rate at which the dirt in the bottom of the tank builds up will be different for every situation. Periodically, this dirt will have to be cleaned out. To do this, the washout valve of the tank should be opened, and the inlet valve to the tank closed. A team of cleaners should enter the tank and using brushes, carefully clean the sediment out of the tank, and clean the walls and floor of the tank. Whilst doing this, it is good to wash the tank with a weak (0.05%) chlorine solution. Normally, this cleaning will be done every week or 2 weeks, but sometimes, it can be done less frequently than this.

It is good to also wash out the chlorination tank periodically, though this will not need to be done as often as the sedimentation tank.

It is very important that great care is taken not to tear the liners of the tanks. Shoes should be taken off, and sharp tools should not be used or taken in to the tank. If the water is highly turbid, a large amount of sludge will be generated, which may be impossible to remove through the 3" bottom outlet. In this case it will have to be removed by hand or sluiced out with a water jet.

Problems if too much aluminum sulphate (alum) is used

At different times, the amount of alum which should be added will vary, depending on the water quality. This means that if the water is dirtier than usual, more alum than usual will have to be used. However***, it is very important that the extra amount added is not excessive, otherwise there will be alum carried over into the drinking water supply***, giving the water a metallic taste. This will not harm the people at the time, but it is possible that after some years, long term detrimental health effects may result. For this reason, great care should be taken that too much alum is not used.

Cleaning of the upflow prefilters is achieved by rapid draindown. Disconnect inlet pipework at a convenient but close section and open the control valve fully. Arrange for washwater flows to be directed away from operational or access areas as they are heavily loaded with silt and will cause ground surfaces to seriously deteriorate. It may be necessary to excavate a washwater collection trench of sufficient size to collect a complete draindown volume and provide a soakaway/silt trap.

6.4 Management and training

In all of the above activities, good management and training is essential to ensure that procedures are followed as intended. A manual should be produced detailing all points relating to the development and operation/maintenance of the system which should include:

- A history of the development of the system.
- Any future upgrading plans.
- Water quality analysis.

- A full set of drawings of the system layout, detailing positions of valves/junctions etc., elevation drawing with pipeline profiles.
- A full written operation schedule with timings for all operations; chemical dosing and quantities, pump operation/maintenance and fuel use, timings for opening and closing of all valves. (Have these available in the operator's own language if they can read.)
- A list of names of all operators, with duties, shift times and back-ups in case of absence/illness etc., pay scales and organogram of staff.
- Details of managers whom operators should report to in the event of breakdown and problems, and who should take action. (These managers must be contactable each and every day either in person or by radio if the operators do not have capacity to effect repairs themselves).

In addition it is essential to:

- Keep a stock of spares and fittings, for an agreed period of time, of items likely to fail, and adequate stock control of these items.
- Keep a stock of chemicals (taking care of the shelf life of chlorine) and fuel sufficient for an agreed period of time and stock control, with clear idea of who buys these and when. Is there a budget available?

The motivation and payment of operatives is another important consideration. Working hours, especially at night when there will be little or no supervision and when operators may go to sleep, need to be set carefully to avoid problems. Payment and incentives, need to be set high enough to encourage work to be proper attendance and performance, while full involvement and explanation will help give the operatives a sense of involvement. Their experience in operating a system should be welcomed and used where appropriate.

Finally there should also be time set aside to train up operators for the systems by going through every step of the operation, seeing that the operators can demonstrate how it is done. This should then be followed up by visits to check on water quality and quantity and to give training revision sessions. Also, it will be essential to get feedback from the users, e.g. the refugees themselves, to ensure that all is well from the user point of view. Community interaction should be incorporated as part of the training.

Appendix 1, WHO water quality guidelines.

Only the most basic parameters of common concern have been set down here. For a comprehensive understanding of water quality parameters, refer to the WHO guidelines for drinking water quality.

- NTU max. recommended value is 5, but preferable<1for disinfection efficiency.
- Taste and odour should be acceptable
- Faecal coliforms should always be 0.
- pH should be between 6.5 - 8.5
- TDS (total dissolved solids): 1000mg/l. The relationship between Conductivity and TDS is: Conductivity (microsiemens/cm) x factor (0.55 to 0.9) = TDS (mg/l)
- Aluminum: 0.2mg/l. Aluminum carry over in the treated water can be checked using the comparator supplied in the FMT kit.
- Ammonia <1.5mg/l. Causes tastes and odour
- Copper <1mg/l. Causes staining of laundry and as health significance <2mg/l.
- Chloride <250mg/l
- Chromium <0.05mg/l. Has health significance.
- Fluoride <1.5mg/l. Has health significance.
- High hardness, no limits but can give rise to consumer complaints through scum deposition
- Iron: 0.3mg/l. Iron usually occurs in ground water and the guideline value is set for aesthetic reasons as iron causes discolouring of the water.
- Lead <0.01mg/l. Has health significance.
- Manganese <0.1mg/l. Causes staining of laundry and as health significance <0.5mg/l.
- Mercury <0.001mg/l. Has health significance.
- Nickel <0.02. Has health significance.
- Nitrate (as NO_3^-) <50mg/l. Has health significance.
- Sulphate <250mg/l. Gives rise to taste and causes corrosion
- Zinc <3mg/l. Gives rise to taste and appearance.

Appendix 1, Sphere standards

Note: Only the relevant standard relating to water quality and quantity have been reproduced here.

Water supply standard 1: access and water quantity

All people have access to a sufficient quantity of water for drinking, cooking and personal and domestic hygiene. Public water points are sufficiently close to shelters to allow use of the minimum water requirement.

Key indicators

* At least 15 litres of water per person per day is collected.
* Flow at each water collection point is at least 0.125 litres per second.
* There is at least 1 water point per 250 people.
* The maximum distance from any shelter to the nearest water point is 500 metres.

Water supply standard 2: water quality

Water at the point of collection is palatable, and of sufficient quality to be drunk and used for personal and domestic hygiene without causing significant risk to health due to water-borne diseases, or to chemical or radiological contamination from short term use.

Key indicators

* There are no more than 10 faecal coliforms per 100 ml at the point of delivery for undisinfected supplies.
* Sanitary survey indicates low risk of faecal contamination.
* For piped water supplies to populations over 10,000 people, or for all water supplies at times of risk or presence of diarrhea epidemic, water is treated with a residual disinfectant to an acceptable standard (e.g. residual free chlorine at the tap is 0.2-0.5 mg per litre and turbidity is below 5 NTU).
* Conductivity is no more than 2,000 MS/cm and water is palatable to users.
* No significant negative health effect due to chemical or radiological contamination from short term use, or from the planned duration of use of the water source, is detected (including carry-over of treatment chemicals), and assessment shows no significant probability of such an effect.

Appendix 2, Oxfam water testing and treatment kits

Oxfam code	Description	What the kit if for
FAS	Aluminium Sulphate (500 kgs)	This kit contains 20 No bags of 17% ground aluminium sulphate
FASD	Alum Suction Side Dosing Kit	Alum dosing pump to be used on suction side of any Oxfam pumps, PR2, P2, P4, P4H
FBR	M-FC Broth for DelAgua Water Testing Kit	2ml ampoule of ready prepared broth for use with Delagua test kit
FCCD	Chlorine Constant Rate Dosing Kit	Chlorine constant rate dosing kit, complete with brackets to fix on side of Oxfam tank
FCH	HTH Chlorine Powder	10 kg of HTH calcium hypochlorite with min 65% available chlorine
FCT	Chlorine Tablets (Tri-chloroisocyanuric acid)	50 No 200gram slow dissolving chlorination tablets
FDS	TDS Conductivity Meter	Total Dissolved Solids sensor, range 100-10,000 ppm (mg/l)
FF	Slow Sand Filtration Kit	Underdrain and other fittings for installation in 1No Oxfam T70 tank to make up a slow sand filter capacity 150m3/hr
FFP	Floating Pot Chlorinator Kit	Plastic floating pot chlorinators for use with code FCT
FK	DelAgua Water Testing Kit – 240v	Test kit including tests for Faecal coliforms, turbidty, chlorine and pH
FKC	Consumables for DelAgua Kit	Consumables for DelAgua test kit
FK10	DelAgua Water Testing Kit – 110v	Delagua test kit with lower voltage supply, particularly for use in South America
FMT	Measuring and Testing Kit	Containing compurgators for , aluminium, total iron, TDS meter, pH meter, thermometer, turbidty tube, and apparatus for conducting a jar test
FPD	Plastic Drum for Dosing	200 litre plastic drum for chemical dosing
FPO	Pooltester for Chlorine/pH Testing	Comparator for testing pH and Chlorine
FPU	14/20 litre water disinfection tablets	200 Pots of 100 tablets, weight 350mg each tablet. Each tablet to contain 70mg of Sodium dichloroisocyanurate, which will provide approximately 2.1ppm available chlorine when used in 20 litres of water or 3ppm in a 14 litre Oxfam water container
FRF	Roughing Filter for T11 Tank	Roughing filter kit designed to fit inside Oxfam T11 tank and operate at around $3.2m^3/m^2/hr$
FTT	Turbidity tube	Plastic tube for measuring turbidty
FUC	Upflow Clarifier (to fit T11 Tank)	Upflow clarifier kit designed to fit inside Oxfam T11 tank and operate from $7\text{-}9m^3/m^2/hr$
FX	Fibertex F-4M Filter Fabric	Non woven fabric for use in slow sand filters, the upflow clarifier and for river intakes

Appendix 3 Treatment system monitoring forms

(Translate these forms to local language as required)

Oxfam water treatment systems, form 1 - water quality monitoring sheet

Location :

Name of technician :

Required frequency of sampling - daily/weekly/monthly (specify)

Date	Sample No Location	Free Cl Res. Mg/l	Inlet turbidity	Outlet turbidity	Aluminium carry over mg/l	pH	No of Faecal coliforms/ 100ml

Oxfam Water Treatment systems, form 2: Consumable usage and water production records

Location :

Name of technician

	Water production (M^3/DAY)	Diesel (litres)	Chlorine Volume of 1% stock solution	Aluminum sulphate Volume of 10% stock solution	Lime (litres/ grams)	Other

Note: Quantities of chemicals used are expressed in terms of volume as this is easier to measure. Chlorine as 1% solution, lime as %, aluminum sulphate as %

Oxfam water treatment systems, form3, pumping tank operation/filling schedule

Location :

Name of technician :

Pump No.	Time of pump operation		Time outlet valve open				Time outlet valve closed			
	Pump on	Pump off	No.1	No.2	No.3		No.1	No.2	No.3	

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Richard Luff

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