WATER TREATMENT DURING RECONSTRUCTION

Introduction

In the aftermath of a disaster, one of the immediate requirements for displaced people is a supply of water, for both drinking and washing purposes. Since the reconstruction process can take many years to be completed, this supply must be sustainable. Conditions for displaced populations are often over-crowded and lacking in sufficient sanitary infrastructure, leading to a breeding ground for human pathogens; water supplies can easily become contaminated and the spread of disease through water for drinking and washing can lead to serious health problems for those exposed.

Whilst it is preferable to have a clean supply of water, this is often not possible in a post-disaster scenario, and it is necessary to treat water to reduce the risk of pathogens spreading to people. After basic treatment has been supplied during the initial emergency stage, upgrades can be implemented to ensure efficient and safe supplies to people as they progress through the recovery process. The provision of infrastructure during the reconstruction process should look to reduce vulnerability and improve living conditions at every stage.

This report draws on information from Practical Action technical briefs Water Treatment Systems and Household Water Treatment Systems. It describes the types of contaminants often found in water supplies in a post-disaster context, some of the treatment types available and how they can be implemented at the different stages of the reconstruction process. An overview is given of some water treatment technologies, with links provided to more detailed technical briefs.

Water Contaminants

The various contaminants that can be found in water supplies are grouped into three general categories:

Biological Contaminants

Biological contaminants can consist of various bacteria from faecal matter and algae for example, but also common are parasitic organisms such as roundworms and flatworms. The lack of sufficient sanitation in post-disaster scenarios can often lead to excreta-based contamination of water supplies. The World Health Organisation has more details on the various biological diseases that can be spread, available here.

Physical Contaminants

Consist of particles and suspended solids; primarily found in surface water. The suspended solids in water can provide a breeding ground for bacteria, and must be removed before consumption.

Chemical Contaminants

Many water sources can contain high levels of chemicals, either through pollution or natural processes. Some examples include high concentrations of nitrates causing cyanosis, arsenic increasing risk of cancer and fluoride causing mottling of teeth. More comprehensive details of chemical contaminants and their effects are provided in the references at the end of this report.

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Water Treatment Classification

The World Health Organisation (WHO) ranks the treatment processes available according to their technical complexity in Table 1, the higher ranking being more complex. It is usually the case that the more complex the system, the higher the capital and operating costs.

Ranking	Examples of Treatment Processes
1	Simple Chlorination Plain filtration (rapid sand, slow sand)
2	Pre-chlorination plus filtration Aeration
3	Chemical coagulation Process optimisation for control of DBPs
4	Granular activated carbon (GAC) treatment Iron exchange
5	Ozonation
6	Advanced oxidation process Membrane treatment

Table 1: Ranking of technical complexity and cost of water treatments
Source: WHO, 2008

In order to ensure water is free from both sediments and pathogens to an acceptable level, a multi-stage treatment is most effective. The Practical Action technical brief Water Treatment Systems describes methods to develop a multi-stage system.

Basic Water Treatment

In an emergency context, water is required immediately after a disaster for displaced populations for both drinking and washing. The supply will most likely be provided by an external organisation (Governmental or NGO-based relief agency) whose responsibility it is to ensure that the supply is safe.

It is a general assumption in these scenarios that a sufficient quantity of safe water is more desirable than a small quantity of high-quality water; the need to ensure all displaced people have access to the supply is the primary objective. The SPHERE project is an initiative set-up by an alliance of humanitarian agencies to ensure that principles and standards for humanitarian responses are coordinated; the project has published a handbook detailing the minimum standards for water quality in an emergency situation, which is available here.

Basic guidelines for treatment of a water source in an emergency scenario are as follows (SPHERE, 2004):

- Start with the best quality water available as treatment procedures are not perfect.
- Filter source and encourage coagulation if possible.
- Disinfect (although this may not be sufficient without further treatment).
- Water quality should be tested for faecal contamination.

It should be assumed that with minimum standards of water supply met, there will be low chemical contamination. All treatment in these circumstances should ensure that bacteriological and physical contamination is minimised:

1) The removal of sediments and suspended solids through methods including aeration, filtration, coagulation, storage, sedimentation and abstraction. The reduction in turbidity of water supplies often leads to much more effective bacteria removal processes.
2) Disinfection to remove disease-causing bacteria (pathogens) through processes including chlorination and solar treatment.

Whilst a relief agency is likely to organise the water supply, there is also a need to ensure people retain a level of independence, and in line with principles of People-Centred Reconstruction, encourage their own construction and/or administration of water treatment methods. Boiling water can ensure complete sterilisation, but requires significant energy inputs that are normally not available in sufficient quantity. Instead, people require practical treatment methods that give the best possible result considering the circumstances.

Some practical solutions are now detailed that can assist with water treatment. They are considered applicable or adaptable to the emergency stage (and further) of the reconstruction process. Key attributes include quick and simple construction and operation, portability and effectiveness.

Point-of-Use Chlorination

Chlorination is a simple but effective method of disinfecting water supplies, killing the majority (but not all) of bacterial contaminations. It is relatively inexpensive and usually readily available in several forms.

When added to water, chlorine destroys the membranes of micro-organisms and kills them. At temperatures between 18°C and 30°C it requires approximately 30 minutes to achieve disinfection, but this can be longer for lower temperature. Additionally, it is only effective in water of low turbidity; silt and sediment can block this process from occurring and the treatment is ineffective, and water supplies should undergo a basic filter treatment before chlorine is added. The more thoroughly the water can be filtered before chlorination the better, although this can be limited in an emergency context.

Chlorination should be undertaken by the dispensing agency, as it is important to add the correct amount; too little can result in ineffective disinfection, whilst too much can leave residual chlorine which is damaging to health. It is unlikely that a correct standard can be upheld, and it would require each individual to have access to measuring equipment to determine water contamination and chlorine levels. WEDC and WHO have compiled a technical note on water chlorination, available here.

Clay Water Filters

A simple method for filtering and storing potable water has been developed by the Sri Lanka Red Cross agency, consisting of a porous clay pot placed into a plastic liner. The plastic liner has a spigot at the bottom to allow controlled access to the filtered water.

The clay filter element is treated with colloidal silver, killing bacteria and removing sediments as water passes through to the receptacle below. Water quality tests have shown in kills approximately 98% of diarrhoea causing bacteria, and can filter up to 40 litres of water per day. The technology has been widely implemented in some areas of Sri Lanka, having been developed in response to the need for safe water supplies for displaced people in the aftermath of the 2004 tsunami.

People who use the device are encouraged to clean and maintain their own pot, helping to develop an understanding of water hygiene in the process.

The Practical Action report 'Clay Water Filters' has a more detailed description of the manufacture and operation of the product. It is available here.

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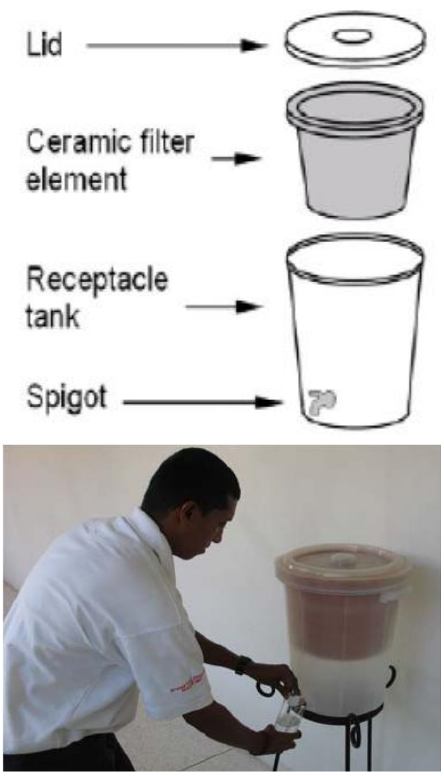

Figure 1: Diagram and picture of Clay Water Filter. Source: Practical Action Technical Brief – Clay Water Filters

Solar Water Disinfection

This is a very simple of method of removing or neutralising pathogens in water; by filling a plastic bottle of contaminated water and exposing to direct sunlight for a few hours. The raised temperature of the water and UV rays from sunlight combine to kill off a variety of protozoa, bacteria, yeasts, viruses, algae and fungi that can exist. The method has been shown to remove up to 99.9% of pathogenic bacteria from water supplies.

Figure 2: Bottles are left for the day
Photo: Practical Action / Zul

The effectiveness of the process is dependent on the intensity of the sunlight (i.e. process can be completed in 6 hours with strong, direct sunlight, but up to 2 days for intermittent sun), and the turbidity of the water. It is recommended the process is ineffective for water with a turbidity of over 30 NTU.

The Practical Action Technical Brief provides more detailed information here.

The above two methods of water treatment are simple and effective processes that can be operated by individual, displaced people in an emergency scenario. The key benefits are that they can be used to ensure most contaminated water supplies from point sources are safe for consumption, with a greatly reduced risk of spread of disease.

Transition

These methods can provide a consistent, safe supply during the early stages of reconstruction. During a transitional stage, it is often unknown how long people will be displaced for, and whether the location is permanent or not. The portability of these methods is essential in this respect.

Once emergency supplies have been secured, a key upgrade to distribution infrastructure is improved storage facilities. These provide much greater opportunity for coagulation and sedimentation, removing physical contaminants and improving the effectiveness of disinfection treatments as well.

Large tanking facilities are outside the scope of this report, but detailed information can be found through various links at the Practical Answers Emergency Relief homepage.

Other Small-Scale Water Treatments (External Sources)

As well as the above examples, there are several other small-scale filter technologies being developed:

Aquabox
http://www.aquabox.org/newsitem.asp?id=135
Emergency relief water tank and filtration kits - It is filled with a selection of warm clothing, useful hardware and hygiene items. It also contains a filter cartridge and a matching supply of water-treatment tablets. Once the welfare contents have been removed, each Aquabox can be used to purify up to 1100 litres of water. The Aquabox Gold is a sponsored box that is filled by Aquabox with welfare items and two filter kits extend its water purification life. AQUA30 is for situations where the need is more prolonged or arises regularly, but permanent solutions cannot yet be provided. AQUA30 is supplied filled with 30 filter cartridges and the required water-treatment tablets.

Potters for Peace
http://www.pottersforpeace.org/
An organisation devoted to socially responsible development and grass roots accompaniment among potters. The organisation was started by the late Ron Rivera born to Puerto Rican parents in the Bronx USA. Its design of ceramic water filter was developed by Guatemalan chemist, Fernando Mazariegos and has water filter projects worldwide.

First Water
Website: www.firstwater.info
Specialists in Low-cost ceramic water filters for emergency and long-term deployment.

Marathon Ceramics
Website: http://www.marathonceramics.com
Small-scale ceramic water filters - Newton water gravity filter systems for emergency preparedness, disaster relief and remote locations. E-water group siphon filter for emergency drinking water or for remote communities schools and hospitals.

Newcastle University
http://www.ncl.ac.uk/press.office/press.release/content.phtml?ref=1157976796
Newcastle University engineers developed a simple water filter. The unit designed by Dr Paul Sallis and others can be made from local materials. The design is based on a mixture of clay and crop residues - such as rice husks or bran – to produce a ceramic filter. Work was done at the International Centre for Diarrhoeal Disease Research in Bangladesh, training village potters to make the filters.

University of Delaware
Researchers have developed an inexpensive, nonchlorine-based technology that can remove harmful microorganisms, including viruses, from drinking water. Developed jointly by researchers in the College of Agriculture and Natural Resources and the College of Engineering, It incorporates highly reactive iron in the filtering process. Currently, the Centre for Affordable Water and Sanitation Technology in Calgary, Canada,

Rotary Australia World Community Service Ltd. – RAWCS
Save Water Save Lives
Email: info@solarwaterpurifier.com
Website: http://www.solarwaterpurifier.com
Solar water distillation purifier project. An initiative of RAWCS Limited Central Region and is under the Save Water Save Lives Committee from the Central Region.

Arsenic
"Remediation-in-a-bucket" technique for As-contaminated drinking water in poor communities"
http://www.geolsoc.org.uk/pdfs/AMD4.pdf
The two components are a water purifier called Slingshot that uses a fraction of the power of alternatives and a Stirling engine based power generator that works on cow dung. The $1500 water purifier will produce 1000 liters of water a day, while the generator produces around 1 kW, which is enough to deliver light to a small village.
http://www.ecofriend.org/entry/slingshot-water-purifier-and-sterling-generator-gadgets-with-a-green-tinge/

LifeSaver
http://www.lifesaversystems.com/
Personal water treatment products

Advanced/Permanent Water Treatment

In more advanced reconstruction contexts, where populations have moved from emergency shelters into more permanent stages of housing, there is more scope to employ advanced methods of water treatment. It is likely that water sources will no longer be distributed and treated by relief agencies, and it may be that higher levels of contamination exist. In these cases, there will be a greater requirement of the community/individual to filter and disinfect the water thoroughly with more advanced techniques.

There are a variety of technologies available to apply more advanced water treatment processes. The feasibility of their installation can depend on numerous factors, including cost, labour requirements and available materials. In general, these options tend to be large-scale and/or more expensive, where the high initial investment and complexity can lead to a secure water source over an extended period. Many of these technologies require external support, with an aim to ensuring the community/user can independently operate and maintain after installation.

Bio-Sand Water Filters

Bio-Sand Filters are a recent, innovative approach to household water treatment, whereby a containing body is filled with gravel and sand layers which allow water to diffuse through them. The water drain is then pumped back up above the sand layer, creating an active bio-film on the surface of the sand, which enables efficient purification of water that passes through.

The filter can produce up to 60 litres of safe water per hour, removing more than 90% of faecal coliform, 100% of protozoa and helminthes, 95 to 99% of zinc, copper, cadmium, and lead, and all suspended sediments. However, further treatment of the water is probably required to remove dissolved compounds such as salt and fluoride or organic chemicals such as pesticides and fertilizers, which pass through the filter.

The technology has several advantages when considering aspects of PCR, including the fact that it utilises many materials that are available locally in poor areas. The filter can produce a high flow rate and is an effective and durable method.

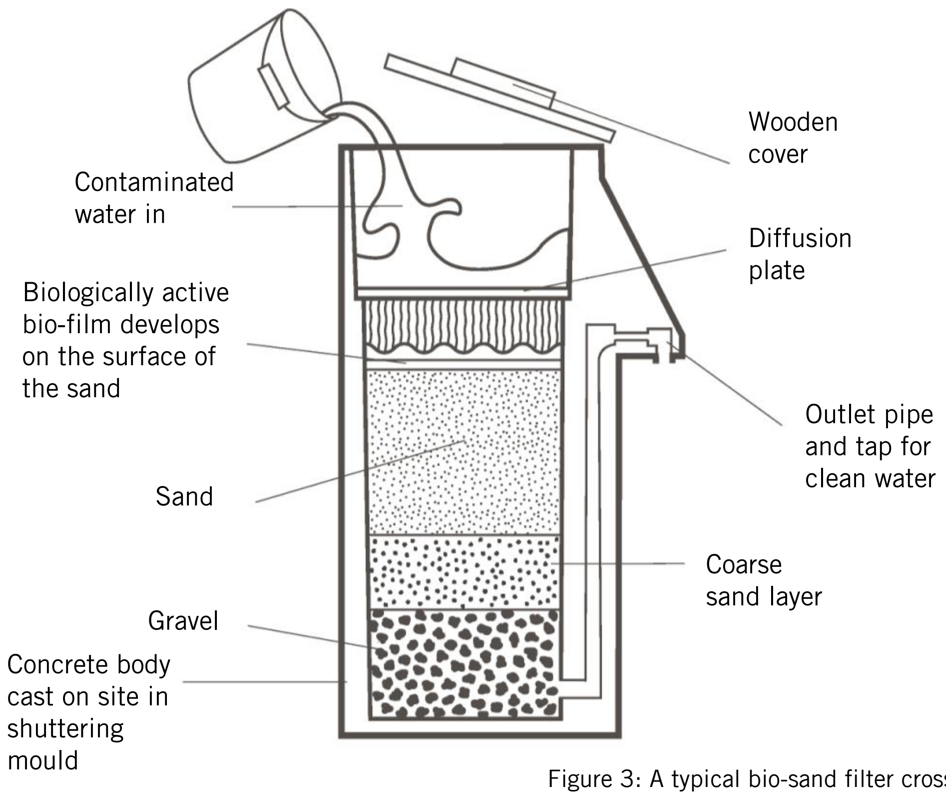

Figure 3: A typical bio-sand filter cross section
Illustration: Practical Action

However, it does require regular and extensive maintenance to ensure that performance does not drop below satisfactory levels; the cleaning of the filter requires significant labour, although this can have benefits in terms of hygiene education and skill sharing. Additionally, it has a bulky and heavy design, putting severe limitations on movability. For these reasons, it is not generally considered practical for the earlier stages of the reconstruction process, but can provide reliable supply of safe water in large quantities once installed.

Further information on the technology can be found in the Practical Action technical brief Bio-Sand Water Filters.

Slow-Sand Filter Treatment

Slow-sand filtration is a very effective method of removing particulate and suspended matter. Essentially a scaled-up version of the household bio-sand filter, it can be used for groundwater containing suspended solids but is more often used to remove organic material and pathogens from surface water, applying aeration and filtering processes to supplied water.

Water stands in a tank 1m above a sand filter bed and moves down at about 0.1- 0.2 m/hr. Different grades of sand can filter out physical impurities and they can also eliminate pathogens as they develop a layer of algae that feeds on the bacteria. This occurs at the top of the sand bed and is called a schmutzdecke. The schmutzdecke is effective at killing and retaining various bacteria, pathogens and viruses, which makes it more effective than a rapid sand filter. The sand filter will block up over time with inorganic matter but this can be removed by backwashing. Inorganic matter can be removed through rough filtering or by using sedimentation tanks.

Slow-sand treatment plants are significant constructions, and require regular maintenance. It is essential that communities that will benefit from the filters are involved in the construction and maintenance processes, allowing for continued use of the filter for several years. The technology is very much suited to permanent housing reconstruction, and allows for the engagement of local populations. Additionally, it could be considered for Internally Displaced Person (IDP) camps that are unlikely to move in the short-term. The community construction and use of a slow-sand plant could be intrinsically linked with some of the principles of PCR.

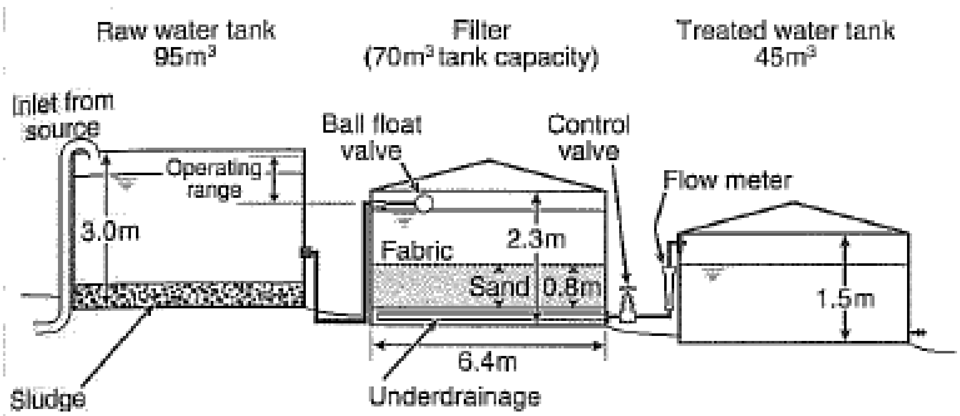

Figure 4: Schematic of a basic Slow-Sand Filter plant
Source: Engineering in Emergencies, © Practical Action Publishing

Sand filter systems are described at length in the document Slow Sand-Filtration Water Treatment Plants produced by Soluciones Prácticas (Practical Action's Spanish Language sister site).

Further information on the technology can also be found at:
http://www.biosandfilter.org/biosandfilter/index.php/item/330

Multi-Stage Filtration

Slow-sand filters are only effective if the turbidity of the water is sufficiently low. One way to ensure that this is the case is to include a multi-stage filtering process in the construction; the initial stage is known as a 'Roughing Filter', due to the large size of the gravel and crushed stones.

The diagram below explains the basic layout of a multi-stage filtration plant. More details are available from the International Water and Sanitation Centre, and can be found at http://www.irc.nl/page/31601.

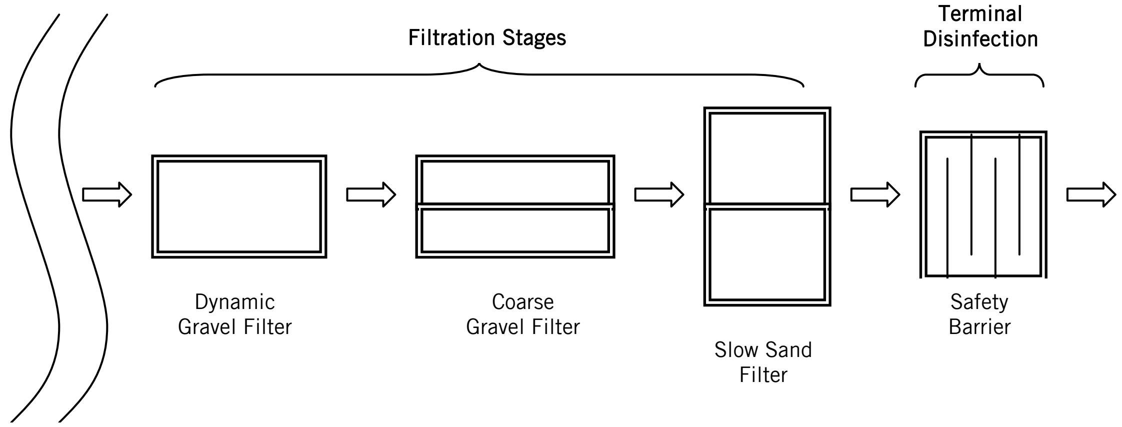

Figure 5: Layout for a multi-stage filtration system (Illustration by A. Elias based on Galvis, G. IRC 2006)

Solar Distillation

Distillation can remove virtually all salt, nitrates, and heavy metal such as arsenic from water as well as pathogens and other biological contaminants from water. Solar distillation is a low cost but low volume approach to treating water. Essentially water is evaporated by the sun and condenses on a cooler surface from where it is collected. A common design of a solar still is shown below; a glass or plastic plate is fixed on top of the still to increase the temperature in the still, and the bottom of the still is lined with a black material such as bituminous paint, butyl rubber, epoxy enamel, fibreglass painted black or aluminium painted black, to act as a heat absorber.

It is also important that the whole still is well-insulated to improve efficiency. The sides and base of the still are typically brick or concrete. Moulding of stills from fibreglass was tried in Botswana. This was more expensive than a brick still and more difficult to insulate sufficiently, but has the advantage of being transportable. This technology may also be suitable for certain transitional stages. More information is available in the Practical Action technical brief Solar Distillation.

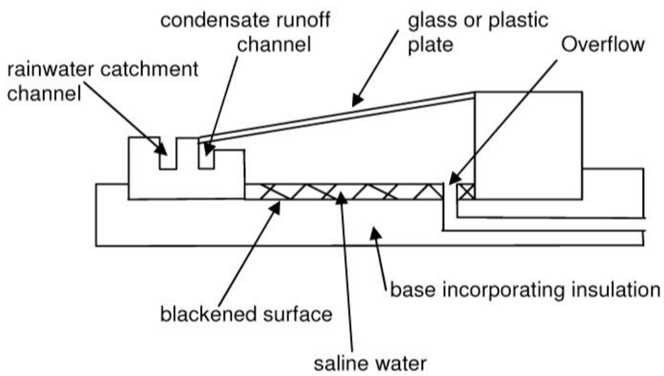

Figure 6: Schematic of a single-basin still. Illustration: Otto Ruskulis for Practical Action.

Conclusion

This brief has covered some of the main practical solutions to water treatment, in the context of the different stages of the reconstruction process. To generalise:

- At the emergency stage of the reconstruction process, quality of water is often secondary to quantity, provided that minimum standards can be met. Relief organisations are likely to control water supplies, and may have to forgo certain treatments if insufficient time or infrastructure exists.
- The application of small scale solutions allows additional treatment of water supplies to take place on a cost-effective and mobile basis.
- Whilst people are displaced in transitional shelters, the upgrade of water distribution and sanitary facilities will likely improve the quality of water from source. Existing treatment facilities can be scaled up or improved.
- Advanced treatment facilities require larger-scale engineering solutions, with extensive community involvement in construction and operation. These are best suited to more permanent stages of reconstruction where benefits can be felt over a longer period.

The technologies in this brief are by no means an exhaustive list, and new innovations may come to market. The following is a list of references and further reading that will elaborate more on the technologies covered here, and provide links to organisations that could provide further solutions:

References & Further Reading

Practical Action documents
Bio-Sand Water Filters
Clay Water Filters
Household Water Treatment Systems
Slow Sand-Filtration Water Treatment Plants
Solar Distillation
Solar Water Disinfection
Water Treatment Systems

'Engineering in Emergencies: A Practical Guide for Relief Workers',
http://developmentbookshop.com/engineering-in-emergencies.html

Oxfam
Water Treatment in Emergencies PDF

UNICEF
Resources on water sanitation and hygiene URL
Arsenic Primer PDF
Ceramic Water Pots in Cambodia PDF

WEDC
Wastewater Treatment Options PDF
Measuring Chlorine Levels in Water Supplies PDF

WHO
Guidelines for Drinking-water Quality URL
Fluoride in Drinking-water PDF
Information Sheets on Water-related diseases URL

IRC
Browse the IRC digital library to find more resources at: http://www.irc.nl/page/100
Arsenic in Drinking Water URL
Waste Stabilisation Ponds URL
Smart Water Solutions URL

Lifewater International
http://www.lifewater.org/resources/tech_library.html

Water Treatment Overview
Methods of Water Treatment (RWS.3.M) PDF
Determining the Need for Water Treatment (RWS.3.P.1) PDF
Taking a Water Sample (RWS.3.P.2) PDF
Analyzing a Water Sample (RWS.3.P.3) PDF
Planning a Water Treatment System (RWS.3.P.4) PDF
Water Treatment in Emergencies (RWS.3.D.5) PDF

Household Water Treatment
Designing Basic Household Water Treatment Systems (RWS.3.D.1) PDF
Constructing a Household Sand Filter (RWS.3.C.1) PDF
Operating and Maintaining Household Treatment Systems (RWS.3.O.1) PDF

Sedimentation Basins
Designing a Small Community Sedimentation Basin (RWS.3.D.2) PDF
Constructing a Sedimentation Basin (RWS.3.C.2) PDF
Operating and Maintaining a Sedimentation Basin (RWS.3.O.2) PDF

Slow Sand Filters
Designing a Slow Sand Filter (RWS.3.D.3) PDF
Constructing a Slow Sand Filter (RWS.3.C.3) PDF
Operating and Maintaining a Slow Sand Filter (RWS.3.O.3) PDF

Disinfection Units
Designing a Small Community Disinfection Unit (RWS.3.D.4) PDF
Constructing a Disinfection Unit (RWS.3.C.4) PDF
Operating and Maintaining a Chemical Disinfection Unit (RWS.3.O.4) PDF

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