HOUSEHOLD WATER TREATMENT SYSTEMS

Domestic water treatment is increasingly popular for people who do not have access to mains water supplies. Household water treatment (HWT) systems allow families to use available water from nearby sources such as springs, wells and rainwater harvesting systems and drink it with reduced risk to health.

Figure 1: A domestic bio sand water filter being used in Peru. Photo: Soluciones Prácticas.

Simple water treatment systems such as sand filtration or ceramic filtration are not as reliable as larger water treatment systems but can be important for people without access to a clean source of water. It is difficult to get a simple and reliable water treatment process for small-scale water supplies. Therefore, if it is possible to use a water source that is already clean then the water treatment becomes less critical.

The following are the basic advice for water supplies

- Start with the best quality water available as treatment procedures are not perfect
- Disinfect (if possible) although this may not be sufficient without further treatment
- For an unprotected source coagulation and sand filtration should be carried out in addition to disinfection
- Water quality should be tested for faecal contamination.

If the source water has been tested and found to be safe then things are obviously going to be easier. However, there are ways of improving the source if it is not safe; covering wells with a concrete slab, keeping animals away form the source, ensuring rubbish is not thrown down the well, the type of bucket used to extract water etc. Tubewells with handpumps are usually quite well protected from contamination if maintained properly. Others sources such as surface water are not safe without treatment.

Household water treatment methods

There are a number of approaches to household water treatment outlined below; some are easier to achieve than others.

Boiling

Although the majority of bacteria and viruses are rendered harmless very rapidly, the boiling of water for a few minutes does not necessarily give complete sterilisation. However, it is necessary to boil water for 20 minutes to ensure full safety. The main disadvantage is the energy consumption.

technical brief

Practical Action, The Schumacher Centre for Technology and Development, Bourton on Dunsmore, Rugby, Warwickshire, CV23 9QZ, UK
T +44 (0)1926 634400 | F +44 (0)1926 634401 | E infoserv@practicalaction.org.uk |
W www.practicalaction.org

Storage
The approach to storage can also help with treating the water in that a carefully designed system with a slow flow of water from the inlet to the outlet will allow the water to settle and provide enough time for pathogens to die off. The water should be stored for 48 hours in a covered tank.

The book *Environmental Health Engineering in The Tropics* states that "for storage tanks a few small leaks in a tank above ground may not be serious in village circumstances, and perfectly adequate tanks may be built of local building materials such as brick or masonry, especially if galvanized wire is laid between courses to give the walls horizontal reinforcement." The tank should be protected so that it doesn't become a breeding ground for mosquitoes which means it should be covered, have ventilation pipes screened with mosquito proof mesh and steps should be taken to avoid breeding sites downstream from the overflow.

Sand filters
Sand filters can work well if they are maintained but this is a difficult task and is often neglected which means that the filters often don't work. It is best using a system where filtering can be done easily and maintenance is not going to become an issue. In some cases that might mean a disposable or replaceable filter or a ceramic filter if these are available from a nearby source. In many cases this will not be a realistic option and alternative approaches need to be considered.

Slow sand filters (velocity of 0.1 to 0.2 m/hr) are one approach for household applications. Different grades of sand can filter out physical impurities and can also eliminate pathogens as they develop a layer of algae, bacteria and fungi that feed on the harmful microorganisms in water. This biofilm is called a schmutzdecke. Sand filters will block up over time with inorganic matter but this can be cleaned out by backwashing. Inorganic matter can be removed through rough filtering or by using sedimentation tanks.

Slow sand filters improve the microbiological quality of the water but do not provide completely clean water and an additional treatment such as chlorination of UV is often needed.

Simple slow sand filters can be constructed with an old oil drum and can be upward filter systems or downward filter systems.

Sand filter systems are described in the document Slow Sand-Filtration Water Treatment Plants produced by Soluciones Prácticas.

This document focuses on household water treatment systems using the slow-sand water filter approach. Some construction guidelines are available at the following website http://www.biosandfilter.org/biosandfilter/index.php/item/330

Ceramic filters
The American Red Cross developed a ceramic water filter in Sri Lanka which seems to be technically very good. The design is aimed at family level water treatment. Practical Action has a fact sheet about this which can be seen at The Ceramic Filter

Disinfection and Sterilisation

Chlorine is an oxidising agent. It is cheap, reliable and easy to add to the water supply but it can produce a nasty taste. Chlorine will kill the algae that clean water in slow sand filters so should only be used after filtering if used together. Chlorine should be added in quantities that leave a residual amount of free chlorine in the water of 0.3mg/l after 30 minutes.

Solutions of chemicals containing free chlorine such as bleaching powder, chlorinated Lime, sodium hypochlorite or HTH. Alternative treatments include chlorine dioxide Cl_2 or ozone O_3.

Ultraviolet (UV) Treatment

UV light can be used to kill pathogens in water if the water does not have a large quantity of physical contaminants which would block the light. It can be done on a large or small scale.

At its most basic level SODIS or Solar Disinfection can be carried out by placing water in transparent plastic bottles which are then left out in direct sunlight thus exposing the pathogens’ to UV light which destroys them. See http://www.sodis.ch/.

Domestic scale bio-sand filters

Practical Action has used bio-sand filters in Peru and in Bangladesh and they have been promoted in many other countries by other organisations. The filters were first used in Haiti in 1999 and their usage is spreading throughout the country as people become more aware of their effectiveness. The following description is of the domestic scale bio-sand filter used in Bangladesh.

Figure 2: Domestic water filer used in Peru. Photo: Soluciones Prácticas.

This Bio-sand household filter is a fairly recent innovation in Bangladesh, but has undergone extensive testing at the University of Calgary in Canada. The filter is a small, household sized adaptation of slow sand filters such that they can be run intermittently.

The Bio-sand filter’s simple technology, its proven effectiveness and availability of production materials are what make it a viable option for Bangladesh. In a country where education is limited, people of all ages, including young children, are able to use the filter and understand how it works.

The system has proven effective and has become one of the most widely distributed devices for household water treatment in developing countries.

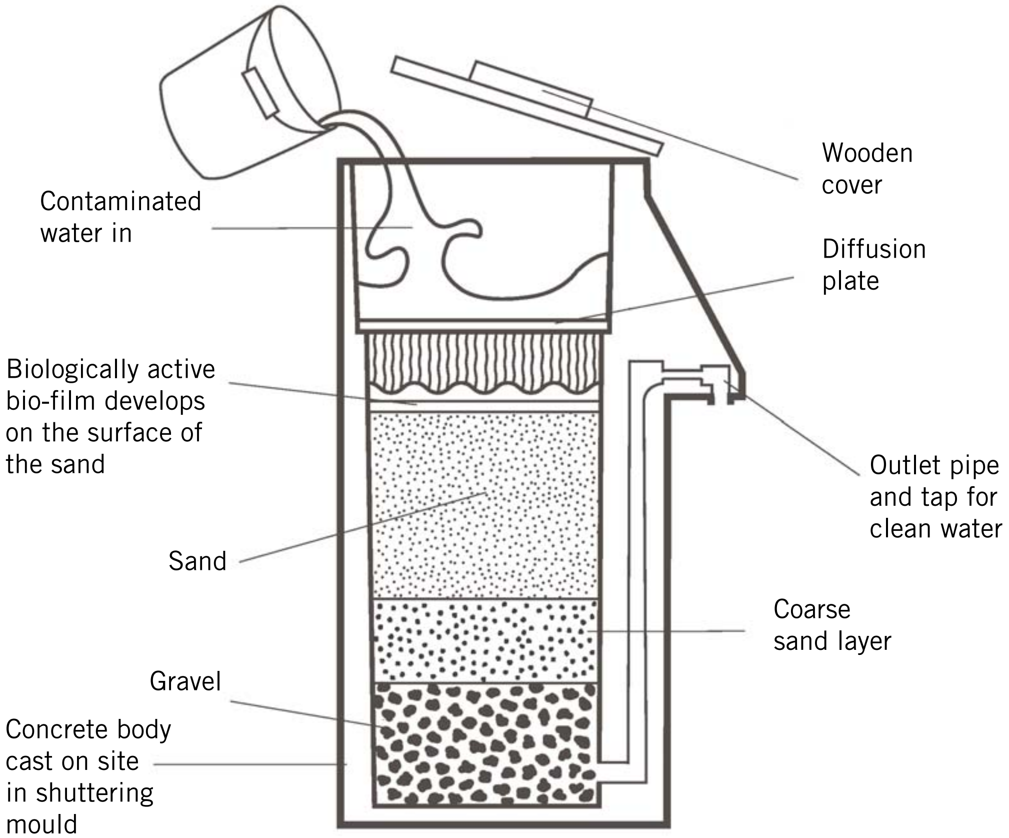

Figure 3: Bio-sand filter cross section.

The filter consists of a layer of gravel overlain with prepared sand media contained within a filter body or box, usually constructed on concrete. A shallow layer of water sits atop the sand, where the biofilm (schmutzdecke) is created.

Operating the filter

- The lid in removed,
- A bucket of water or other container is poured into the top of the filter.
- The diffusion plate slows the force of the water.
- Water then travels slowly into the biological layer at the top of the sand.
- Water continues slowly through the sand bed.
- After passing through both levels of gravel, the water is propelled up and out.
- Then treated water is collected in a clean container.

Amount of Water Treated

Household bio-sand filters typically provide 30 to 60 litres of water per hour, which is sufficient for a family of five to ten members. The flow rate may decrease over time as the filter becomes clogged, but can be restored with cleaning.

Contaminant removal

Bio-sand filters have been shown to remove more than 90% of faecal coliform, 100% of protozoa and helminthes, 95 to 99% of zinc, copper, cadmium, and lead, and all suspended sediments. Bio-sand filters have also been shown to remove 76 to 91% of arsenic, reducing it to acceptable concentrations. These filters do not sufficiently remove dissolved compounds such as salt and fluoride or organic chemicals such as pesticides and fertilizers. The biological layer's effectiveness is influenced by temperature. Ammonia oxidation stops below 6° Celsius and alternative treatment methods are required below 2° Celsius. Additionally, because bio-sand filters are not able to handle high turbidity, they may become clogged and ineffective during monsoon or rainy seasons.

Ease of Use

Bio-sand filters require daily fillings during the 2 to 3 weeks when the biological layer is growing. Bio-sand filters also require regular cleaning, which involves agitating the water above the biological layer. The filter will require 1 to 2 weeks of non-use after agitation to allow for the regrowth of the biological layer. On occasion, the sand in the filter needs to be cleaned as well. There are several different methods to clean the sand, though all of them require significant labour, significant training, or high cost. User error has also been found to affect the filters' efficacy, especially because of the required 2 to 3 week non-use period for growing the biological layer. Bio-sand filters can be fabricated locally in because they use common materials.

Benefits & drawbacks

Advantages

- Removal of turbidity, colour, odour.
- Good microbial removal.
- High flow rate.
- Can be constructed of local materials.
- Income generation.
- Durable.
- Minimal maintenance.

Drawbacks

- Not 100% microbial removal; may require post-disinfection.
- Limited transportation due to weight.
- Turbidity should not exceed 100 NTU.

Costs

- Capital Costs: Tk. 1450.00 – Tk. 1900.00
- Operation and Maintenance: Minimal.

There may be educational and training costs associated with teaching users how to properly maintain their filters. Costs will vary across regions depending on the availability of materials and labour.

Arsenic Removal by Bio-sand Filter

Bio-sand filters may be used to remove arsenic from well water based on the principles of the co-precipitation and filtration method.

A variety of technologies have been used for the treatment of arsenic in water, including conventional co-precipitation with ferric chloride, lime softening, filtration using exchange resins and adsorbents.

The divalent iron concentration is in the range of 0.2-12 mg/l and is positively correlated with arsenic concentration in the groundwater. Fe/As ratios of greater than 40 (mg/mg) is required to reduce arsenic to less than 50 mg/l in Bangladesh well water. Arsenic removal by the bio sand filtration process included precipitation of arsenic by adding a packet of iron nails to the top chamber.

After mixing the water with the iron for a few minutes, the iron will be oxidized to form ferric hydroxide that passes through the sand bed by gravity removing the precipitates. Clean water is collected from the outlet of the filter in the conventional way.

Also see A Small-scale Arsenic and Iron Removal Plant Practical Action Technical Brief

Small-scale water filter equipment

There are a number of options for household-scale water treatment which Practical Action has not had any direct involvement with.

The Red Cross

The American Red Cross working with the Sri Lankan Red Cross, has developed a ceramic filter within a plastic bucket which was originally made for the post tsunami situation and is now being used in general rural situations, details of which are on the Practical Action website. See The Ceramic Filter.

Aquabox

P.O. Box 5398
Matlock
Derbyshire
DE4 4ZP
United Kingdom
Tel: & Fax: +44 (0)1629 825178
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

US office – tom@firstwater.info
UK office simon@firstwater.info
Website: www.firstwater.info
Specialists in Low-cost ceramic water filters for emergency and long-term deployment.

Marathon Ceramics

P. O. Box 24547
Seattle
WA98124
USA
Tel: (206) 624 0571
Fax: (206) 343 4320
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
PO Box 233, St Agnes
South Australia 5097
Australia
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
LIFESAVER Systems, Old Bakery, 7 Tuddenham Avenue
Ipswich
IP4 2HE
United Kingdom
Fax: +44(0)1473 232656
E-mail: mcihael@lifesavesystems.com Michael W Pritchard
E-mail: info@lifesaversystems.com
http://www.lifesaversystems.com/
Personal water treatment products

References and further information

CAWST - Centre for Affordable Water & Sanitation Technology
12 - 2916 5th Avenue NE
Calgary, Alberta
T2A 6K4
Canada

technical brief

Tel: +1 403 243-3285
Fax: +1 403 243-6199
http://www.cawst.org
Household water treatment systems
http://www.cawst.org/en/resources/pubs/category/25-fact--sheets-academic
Bio-sand filters
http://www.cawst.org/en/resources/pubs/category/23-technical-updates
The full bio-sand filter construction manual
http://www.cawst.org/en/resources/pubs/category/12-biosand-filter-project-implementation

Manz Water Info
David Manz, PhD.
University of Calgary
http://www.manzwaterinfo.ca/
Concrete Bio-Sand Water Filter Construction Manuals, Dr. David H. Manz, P. Eng., P. Ag. (May 2008) ACAD Drawings of BSF Steel Mould, Dr. David H. Manz, P. Eng., P. Ag. (April 2010)
BioSand Water Filter Guidance Manuals, Dr. David H. Manz, P. Eng., P. Ag. (January 2009, updated July 2010)

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

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

Practical Action
The Schumacher Centre for Technology and Development
Bourton-on-Dunsmore
Rugby, Warwickshire, CV23 9QZ
United Kingdom
Tel: +44 (0)1926 634400
Fax: +44 (0)1926 634401
E-mail: inforserv@practicalaction.org.uk
Website: http://practicalaction.org/practicalanswers/

Practical Action is a development charity with a difference. We know the simplest ideas can have the most profound, life-changing effect on poor people across the world. For over 40 years, we have been working closely with some of the world's poorest people - using simple technology to fight poverty and transform their lives for the better. We currently work in 15 countries in Africa, South Asia and Latin America.