# ALTERNATIVE WATER TREATMENT TECHNOLOGIES

A number of water treatment methods that employ simple, low cost technology are available. These methods include straining; aeration; storage and settlement; disinfection by boiling, chemicals, solar radiation; and filtration; coagulation and flocculation; and desalination. The following classification is based on Skinner and Shaw.[29] The different methods are presented alphabetically.

**Aeration** can be accomplished by vigorous shaking in a vessel part full of water or allowing water to trickle down through one or more perforated trays containing small stones. Aeration increases the air content of the water, removes volatile substances such as hydrogen sulfide, which affect odor and taste, and oxidizes iron or manganese so that they form precipitates which can be removed by settlement or filtration.

**Coagulation and flocculation.** If water contains fine suspended solids, coagulation and flocculation can be used for removal of much of the material. In coagulation, a substance is added to the water to change the behavior of the suspended particles. It causes the particles, which previously tended to repel each other, to be attracted towards each other, or towards the added material. Coagulation takes place during a rapid mixing or stirring process that immediately follows the addition of the coagulant.

The flocculation process, which follows coagulation, usually consists of slow gentle stirring. During flocculation, as the particles come into contact with each other, they cling together to form larger particles which can be removed by settlement or filtration. Alum (aluminum sulfate) is a coagulant used both at the household level and in water treatment plants.[31, 32] Natural coagulants include powdered seeds of the *Moringa olifeira* tree and types of clay such as bentonite.

**Desalination.** Excessive chemical salts in water make it unpalatable. Desalination by distillation produces water without chemical salts and various methods can be used at household level, for example to treat seawater. Desalination is also effective in removing other chemicals like fluoride, arsenic and iron.

**Disinfection** is a way of ensuring that drinking water is free from pathogens. The effectiveness of chemical and solar disinfection, and to a lesser extent boiling, is reduced by the presence of organic matter and suspended solids.

**Disinfection by boiling.** A typical recommendation for disinfecting water by boiling is to bring the water to a rolling boil for 10-12 minutes. In fact, one minute at 100ºC. will kill most pathogens including cholera and many are killed at 70ºC. The main disadvantages of boiling water are that it uses up fuel and it is time-consuming.

**Chemical disinfection.** Chlorination is the most widely used method for disinfecting drinking water. The source of chlorine can be sodium hypochlorite (such as household bleach or electrolytically generated from a solution of salt and water), chlorinated lime, or high test hypochlorite (chlorine tablets). Iodine is another excellent chemical disinfectant that is sometimes used. Iodine should not be used for extended periods (longer than a few weeks). Both chlorine and iodine must be added in sufficient quantities to destroy all pathogens but not so much that taste is adversely affected. Deciding on the right amount can be difficult because substances in the water will react with the disinfectant, and the strength of the disinfectant may decline with time depending on how it is stored.

**Solar disinfection** uses solar radiation to inactivate and destroy pathogens present in water. Treatment consists of filling transparent containers with water and exposing them to full sunlight for about five hours (or two consecutive days under 100 percent cloudy sky). Disinfection occurs by a combination of radiation and thermal treatment (the temperature of the water does not need to rise much above 50ºC). Solar disinfection requires relatively clear water (turbidity less than 30NTU). More information on solar disinfection is available on the website www.sodis.ch.

**Filtration** includes mechanical straining, absorption and adsorption, and, particularly in slow sand filters, biochemical processes. Depending on the size, type and depth of filter media, and the flow rate and physical characteristics of the raw water, filters can remove suspended solids, pathogens, and certain chemicals, tastes and odors. Straining and settlement are treatment methods that usefully precede filtration to reduce the amount of suspended solids that enter the filtration stage. This increases the period for which a filter can operate before it needs cleaning or replacing. Coagulation and flocculation are also useful treatments to precede settlement and improve still further the removal of solids before filtration.

**Storage and settlement.** Storing water in safe conditions for one day can result in the die-off of more than 50 percent of most bacteria. Longer periods of storage will lead to further reductions. During storage the suspended solids and some of the pathogens will settle to the bottom of the container. Water removed from the top of the container will be relatively clear (unless the solids are very small such as clay particles) and contain fewer pathogens. The three-pot treatment system where raw water is added to the first pot, decanted into the second pot after 24 hours and into the third pot after a further 24 hours, exploits the benefits of storage and settlement.

**Straining.** Pouring water through a clean cotton cloth will remove a certain amount of the suspended solids or turbidity. Special monofilament filter cloths have been developed for use in areas where Guinea-worm disease is prevalent. The cloths filter out the copepods which are intermediate hosts for the Guinea-worm larvae

The following tables (Figures 19 and 20) describe the systems currently promoted for household treatment in developing countries, the advantages and constraints of each system, and costs. Figure 19 also indicates whether published reports of lab tests or field trials of household applications are published in the epidemiologic or environmental literature. Promotion and education are essential elements for the successful implementation of any of these systems. The costs given in Figure 20 do not include the costs of promotion and education leading to behavior change because the major determinant of these costs is likely to be the context or setting in which the treatment systems are being promoted. Promoting household treatment in a setting where there are trained extension agents and community health promoters is very different from working in communities and neighborhoods where there is no institutional capacity.

## Figure 19: Household Treatment Systems – Advantages and Constraints

| System | Process | What is Removed | Published lab tests | Published field tests in developing countries | Advantages | Constraints |
|---|---|---|---|---|---|---|
| Aeration | Shaking part-full container or some form of cascade that exposes water to air | Some taste and odor removal, oxidizes iron and manganese facilitating removal by filtration | No | No | Low-cost component of iron and manganese removal | Limited removal, normally used in combination with other treatment methods |
| Boiling | Bring water to rolling boil for 10-12 minutes | Kills nearly all waterborne pathogens | Yes | Yes | Materials available in most households | Time to gather firewood. Cost of fuel. Increased demand for firewood contributes to deforestation |
| Ceramic filters | Water passes (by gravity or siphon) from outside to inside of unglazed, ceramic cylinder (often called a candle). Good quality ceramic has a pore size of 0.2 microns. Some candles are impregnated with silver to kill pathogens. In some systems, candle filter is preceded by a polypropylene rope filter to remove suspended particles or packed with activated carbon to remove organic chemicals and tastes. | Suspended solids and pathogenic organisms. In theory viruses can pass through 0.2 micron pore but they are normally attached to other material and are prevented from passing. | No | No | Simple and robust. | Blind quickly if water contains suspended solids. Suspended solids are removed by scrubbing candle and scrubbing wears away ceramic material. Candles are relatively expensive. |

## Figure 19: Household Treatment Systems – Advantages and Constraints (continued)

| | | | | | | |
|---|---|---|---|---|---|---|
| Chlorine tablets | Disinfection with calcium hypochlorite or trichloroisocyanuric acid tablets | Inactivates or destroys nearly all waterborne pathogens, oxidizes organic substances | Yes | Yes | Relatively easy to distribute and use, particularly in emergencies. Residual effect. | Not locally available in many developing countries, have to be imported. Expensive for long term use. Dose depends on organic material, etc in water. Available chlorine in tablet can decline with age. Adequate contact time required. |
| Rapid sand filters | Use coarser sand and higher flow rate than slow sand filters to remove impurities by sedimentation, adsorption, straining, chemical and microbiological processes. | Suspended solids especially after coagulation and flocculation. | No | No | Relatively small and compact. | Not effective at removing pathogens. Needs system for backwashing. |
| Safe water system (sodium hypochlorite + safe water container + social marketing + education) | Disinfection with locally available chlorine source (sodium hypochlorite solution generated from salt and water or purchased as bleach), container with faucet & narrow neck | Inactivates or destroys nearly all waterborne pathogens, oxidizes organic substances | Yes | Yes | Complementary package of disinfection, safe water container and hygiene promotion. | Local supply of hypochlorite must be continously available, strength of hypochlorite solution and raw water quality must be relatively constant, otherwise dosing must change. Adequate contact time required. |
| Slow sand filters | Use a relatively fine sand and a low filtration rate to remove impurities by sedimentation, adsorption, straining, chemical and microbiological processes. | Substantially reduces pathogens (microbiological is main mechanism for removal) | No | No | Pathogen reduction but not complete removal. Locally available materials. | Only suitable for raw water with a turbidity of less than 20 NTU. Requires careful maintenance. |

## Figure 19: Household Treatment Systems – Advantages and Constraints (continued)

| | | | | | | |
|---|---|---|---|---|---|---|
| SODIS (solar disinfection + social marketing + education) | Disinfection by UV radiation & heat through exposure to full sunlight for 5 hours in transparent plastic bottle | Inactivates or destroys most waterborne pathogens | Yes | Yes | Uses plastic bottles which are easy to handle, convenient for storage and transportation, and reduce risk of recontamination. Sustainable system that does require consumables except for bottles. | Requires favorable climatic conditions. Only suitable for water with turbidity of less than 30 NTU. |
| "Sorption" or "catalytic" filters | Water passes through a finely ground filter medium composed of zeolite or similar. Impurities chemically bond with filter medium. Pore size in medium is about 2 micron. | Taste, odor, chlorine, and suspended solids, pathogens, volatile organic compounds, and heavy metals. | No | No | Very simple to use – small filters are attached to the cap of a water bottle. User simply fills the bottle with raw water and sucks on a spout in the cap, drawing the water through the filter. Removes nearly all impurities. | Filters are easily blinded by suspended solids. Small filters set in water bottle cap have a limited life being capable of filtering a maximum of 750 liters of water before media is used up. Filters specially formulated for arsenic removal have an even shorter life: filtering about 100 liters. Sorption filters are relatively expensive. |
| Storage & settlement | Raw water is added to the 1st pot, poured or preferably siphoned into 2nd pot after 24 hours, and into 3rd after further 24 hours | About 50 percent of most bacteria die-off, schistosomiasis cerceriae die-off, significant removal of turbidity | No | No | Pots available in most households | Only partial removal of pathogenic organisms |
| Straining | Pour water through monofilament cloth | Copepods (cyclops) containing Guinea-worm larvae, some turbidity | Yes | Yes | Simple method for prevention of Guinea-worm. In areas where copepods harbor *V. cholerae*, can reduce, but not eliminate transmission. | Cloth must always be used with same surface uppermost. Limited removal of other pathogens. |

**Figure 20. Household Treatment Systems – Costs**

| ***System*** | ***Imported items*** (shipping costs and customs duties add to cost) | ***Initial per capita cost* of hardware*** (5 person household) | ***Annual operating cost per capita*** (5 person household & 10 liters of treated water per day) |
|---|---|---|---|
| Aeration | None | None | None |
| Boiling | None | None | Time to gather firewood. Cost of fuel. Deforestation. |
| Ceramic filter | Filter candles | $5 ($20-25 per system) | $1 (replace $5 filter annually) |
| Chlorine tablets | Tablets | None | $6 |
| Rapid sand filter | None | Bucket or other container for sand | Time to gather and clean sand |
| Safe Water System | Cells for generating hypochlorite | $1.60 (2 plastic 20 liter water containers per household, $4.00 per container) | $0.60 |
| Slow sand filter | None | Bucket or other container for sand | Time to gather and clean sand |
| SODIS | None | Cost of black paint for used plastic bottles | None |
| Sorption filter | Filter media | $7.50 (one filter per person) | $37.50 (replace filter five times per year) |
| Storage and settlement | None | Cost of three pots | Cost of three pots (zero after initial investment for every year that pots last) |
| Straining | Monofilament cloth | Depends on location | Depends on location |

*All cost are estimates based on data in 1999.