Chapter Nine

Household Water Treatment: A Summary of Methods and Techniques

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The Need for Household Water Treatment

People in many parts of the world are exposed to disease causing pathogens on a daily basis due to the consumption of unclean water. Drinking water is prone to contamination at the source, within the distribution system, and during collection. Additionally, the unhygienic handling of water during transport and within the home can also contaminate water which was previously safe. Therefore, it is often the case that people with access to improved water supplies through piped connections, protected wells, or other improved sources are, in fact, exposed to contaminated water as well. (WHO, 2007).

Research indicates that household water treatment (HWT) can have a significant impact on improving the health of its users. For example, diarrhoeal episodes are reduced by 25% through an improved water supply, 32% by improved sanitation, 45% through hand washing, and 39% because of HWT and safe storage. (Fewtrell. et al., 2005).

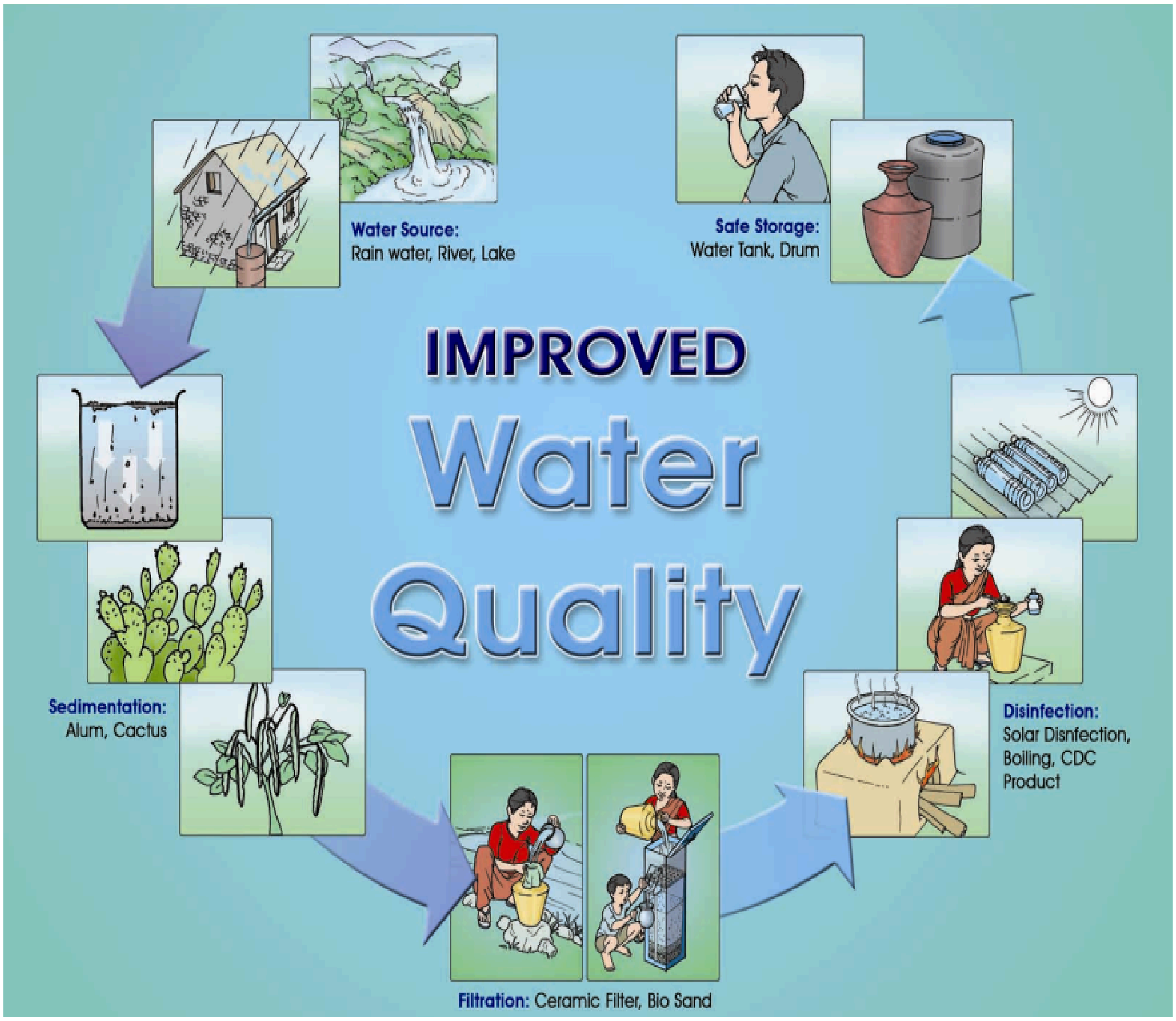
Step 1	Sedimentation/Settling Suspended materials in water, such as particles of sand, clay, and other materials can be substantially removed simply by allowing the water to settle naturally. Bacteria and viruses are often attached to particles; therefore, sedimentation will also reduce bacterial concentrations. Assisted sedimentation speeds the settling process through the use of coagulants and flocculants. These are natural and synthetic chemicals that cause suspended particles to clump together, thereby increasing the speed with which they settle.
Step 2	Filtration Filters can remove pathogens in a variety of ways, to include straining, adsorption, and biological processes.
Step 3	Disinfection The destruction of organism cell walls by oxidation is known as disinfection. Disinfection typically involves the addition of chemicals such as chlorine. It can also be induced by ultraviolet radiation, such as natural sunlight or artificial UV rays.

The Multi-barrier Approach to Safe Water

The multi-barrier approach reduces the risk of drinking unsafe water, by upholding the following initiatives:

- The protection of water sources
- The use of an appropriate pre-treatment storage container
- The correct operation of a series of treatment steps
- The hygienic storage and use of treated water

This process is depicted in the diagram.



Similar to a community or municipal water treatment system; household water treatment processes follow 3 major steps.

Step One: Sedimentation

Natural Settling

The process of natural settling allows turbid water to stand undisturbed so that the suspended particles settle out. Methods that make use of this simple process include 3-pot settling, large container settling and surface collection from lakes or ponds. Simple settling, however, can only partially reduce the amount of suspended particles and pathogens in the water. The time required to achieve acceptable results depends on the nature of the water and the size of suspended particles. The process will take anywhere between one hour to two days, but alternative methods should be considered for lengths exceeding two days.

Advantages	Disadvantages
• Low cost: free if a container is already available. • Simple and easy to do.	• Time required is variable, depending on initial and desired water quality. • Does not remove all turbidity.

The 3-Pot System

The 3-pot system combines natural settling with a 24-hour period of water storage. If contaminated water is stored for a period of time, some bacteria and viruses will die off.

Advantages	Disadvantages
• Simple, easy to do. • Due to the 24-hour storage period, some pathogens are removed.	• Time consuming. • Labour intensive.

Assisted Sedimentation Using Coagulants

Assisted sedimentation is the practice of adding coagulants to turbid water in order to accelerate the settling of suspended particles. A coagulant is a substance, which reacts and combines with particles in the water forming larger clumps of particles, which are more easily removed by settling and/or filtration. Examples of coagulant agents include aluminium, iron salts, and natural plants to include as specific types of cactus and the seeds of the moringa tree.

The following procedure is commonly used to prepare seeds for use as a coagulant:

- Dry and grind the seeds to a fine powder.
- Mix the powder with the water to be treated; the quantity of powder and volume of water depends on the type of seed used:
    - In the case of Moringa Oleifera, add 50-150mg/litre.

  - For peach or bean seeds, add 300-500mg/litre of water.
- Mix for 5 to 10 minutes.
- Leave to stand until the particles settle, then decant the treated water.

Advantages	Disadvantages
• Coagulants are widely available. • Natural coagulants are often of low cost and sometimes free. • Removes some turbidity, bacteria, and chemical contaminants. • Simple and easy. • Widely used in many parts of the world.	• Recurring costs can be high depending on the type of coagulant used. • Time consuming to process and prepare natural coagulants.

Step Two: Filtration

Water filtration technologies such as the biosand filter, Kanchan arsenic filter, ceramic filter, and the ceramic candle filter will remove most solid matter and a large portion of micro-organisms. Many of these are commercially produced filters, which are costly, but some filters can be made using locally available material. Straining can also be considered a form of filtration.

Straining

A cloth fabric can be used to strain particles out of water. Typically, a sari cloth that is folded 8-10 times is used as a cloth filter. Water is poured through the folded cloth to strain particles out of the water.

Advantages	Disadvantages
• Low cost: Rps.0 if old sari cloth is available. • Time required is minimal. • Simple and easy to do. • Removes some turbidity and bacteria (particularly cholera when it is associated with copepods present in the aquatic environment).	• Requires washing of cloth or sari after use.

The Biosand Filter

The biosand filter is an adaptation of a traditional slow sand filter, which allows it to be built on a smaller scale and to be operated intermittently. These modifications make the filter suitable for use at the household level.

As water passes through the filter there are four processes, which simultaneously occur to remove pathogens and particles from the water.

1. Mechanical trapping: Mechanical trapping of particles and micro-organisms occurs in the small pore spaces between the sand grains.
2. Predation: As in a conventional slow sand filter, a biological layer forms at the surface of the sand bed. This bio-layer houses micro-organisms that prey on other organisms and pathogens in the water and consume organic matter as food.
3. Adsorption: Adsorption is a process where micro-organisms, particles and some compounds stick to the surface of the sand grains due to dispersive, polar or ionic physical forces. Sand grains will adsorb viruses, iron and other small particles; adsorbed micro-organisms die off or are inactivated.
4. Natural death: Many pathogens will be killed or inactivated as a result of the relatively hostile environment within the filter's sand bed where there is no light, little oxygen, and few nutrients. Furthermore, the lifespan of many micro-organisms is quite short, so the number of pathogens will be reduced due to the natural die off rate.

A bucket of contaminated water can be poured into the top of the biosand filter as required. The water flows through the filter and is collected in another storage container.

The biosand filter is comprised of six distinct regions: 1) influent reservoir, 2) supernatant, 3) biolayer, 4) biological zone, 5) sand zone, and 6) gravel zone.

Plastic commercially produced filters are available in several countries.

Advantages	Disadvantages
• Functional, durable and affordable. • User-friendly. • Produces good quality water.	• Cannot remove some dissolved substances (e.g. salt, hardness), some organic chemicals (e.g. pesticides and fertilizers) or color. • Cannot guarantee pathogen-free water.

The Kanchan Arsenic Filter

The Kanchan Arsenic Filter (KAF) was developed at Massachusetts Institute of Technology (MIT), in collaboration with the Environment and Public Health Organization (ENPHO) of Nepal. The KAF is a household slow-sand filter with the capacity to remove both microbial and arsenic contamination. The design of this filter is similar to the biosand filter, but, here, the diffuser plate is replaced by a deep diffuser basin filled with 5 kg (11lbs) of non-galvanized iron nails and a layer of brick chips. In addition to the concrete version of the filter, the MIT-ENPHO team has developed a small plastic version using off-the-shelf plastic water buckets available in Nepal.

After coming in contact with water and air, the iron nails in the diffuser basin quickly rust. Iron rust (ferric hydroxide) is an excellent adsorbent for arsenic. When arsenic-contaminated water is poured into the filter, arsenic may stay in the diffuser box (i.e. adsorbed to the surface of the rusted nails in the box), or the arsenic-loaded iron particles are flushed down and trapped on top of the fine sand. The purpose of the brick chips is to protect the iron nails from being disturbed by the force of the incoming water.

The KAF can remove 85% to 95% arsenic in the raw water. The iron nails will lose their capacity in three to five years if the raw water has up to 500 ug/L of arsenic, and, at that time, replacement of the iron nails is necessary.

Advantages	Disadvantages
• Removes 85 – 95% of arsenic from water. • Functional, durable and affordable. • User-friendly. • Produces acceptable water quality.	• Can not remove some dissolved substances (eg. salt, hardness), some organic chemicals (pesticides and fertilizers) or color. • Can not guarantee that water is completely pathogen free.

Ceramic Filters

Carefully prepared clay is moulded into the required shape for the filter and then fired in a kiln. Pores in the body of the filter allow water to pass through but retain particles and pathogens. If properly constructed and operated, a ceramic filter can produce good quality water.

Frequently, colloidal silver is applied to the ceramic surface. Silver in its ionic colloidal state has antibacterial properties that help reduce the bacteria content in the water.

Advantages	Disadvantages
• Removes 99 – 100% of fecal coliforms. • Some removal of turbidity and iron. • Low cost: one new model projected at US $3.50 for the two-container system. • User friendly.	• The flow rate is 1.5-3 litres per hour or approximately 15-30 litres of water per day. • Filters are fragile and commonly do not last more than two years. • Turbid water can result if the filter becomes plugged. • Limited removal of viruses and arsenic.

Ceramic Candle Filters

The ceramic candle filter has one or more porous hollow cylindrical 'candles' made of kiln-fired clay, which may be coated, with colloidal silver. It can filter particles as small as 0.2 microns, removing all disease-causing bacteria and protozoa. Because the ceramic filter can be cleaned many times, more water can be filtered at a fraction of the price of a unit with a non-recoverable filter.

A typical filter unit includes a raw water reservoir, a closed storage reservoir for the filtered water and a tap to dispense the filtered water.

Advantages	Disadvantages
• Removes bacteria, protozoa, helminths, and turbidity. • Easy to use. • Costs $2-10 US for filter, $7-20 US for system.	• Produces 1.5-3 litres of water per hour, up to approximately 18 litres of water per day. • Filters are fragile and commonly do not last more than two years. • Turbid water can result if the filter becomes plugged. • Rigorous quality control during manufacturing is essential for effective filters.

Step Three: Disinfection

Disinfection processes include the use of chemicals such as chlorine and also the effects of ultraviolet radiation.

Pathogens and other micro-organisms can be concealed by organic and inorganic matter in the water and can thus be protected from contact with the disinfecting agents. Doses of chemical disinfectants can be increased up to a point to resolve this dilemma, but the best solution is to reduce turbidity via one of the processes mentioned in Step 1 and/or Step 2.

Chlorination

Chemical disinfection is commonly done using chlorine; it is relatively affordable, widely available and effective. Chlorine is an oxidizing agent, which reacts with organic matter, killing bacteria and viruses, but does not inactivate pathogenic parasites such as Giardia, cryptosporidium and helminth eggs. Chlorine also oxidizes manganese, iron and hydrogen sulphide.

Chlorine products suitable for household level water disinfection are available in liquid, powder and granular form. Household bleach (sodium hypochlorite) is the most common chlorine product that is appropriate for household water treatment.

The following table lists common chlorine generating products and their typical chlorine content or percentage strength.

Product	Strength	Remarks
HTH - High Test Hypochlorite (calcium hypochlorite)	65% - 70%	Usually in granular form. Stable: approximately 2% active chlorine loss per year.
Chlorinated Lime, (bleaching powder)	30%	Usually in powder form. Not stable.
Household Bleach (sodium hypochlorite)	2.5% - 10%	Liquid form. Not stable: only use if stored away from heat and light and manufactured within three months of use.
NaDCC (sodium dichloro-isocyanurate): used in products such as "Aquatabs"	50% - 60% as granules. (5mg to >5g active chlorine per tablet)	Usually in tablet form, also available in granular form. Tablets are pre-dosed for water treatment and/or disinfection uses. Very stable: shelf life of approximately five years.

In some markets, chlorine solutions specifically produced for household water treatment are readily available. For example, in Nepal, the brand Piyush is available in a 0.5% chlorine solution in a 60mL bottle.

Advantages	Disadvantages
• The chlorine chemical destroys the cells of biological contaminants and kills them. • Inexpensive: \$0.40 to \$0.80 US per family per month. • Removes bacteria and viruses effectively. • Easy to use at a household level.	• Not effective at removing protozoa or turbidity. • Requires a minimum of 30 minutes contact time. • Requires clear water to be most effective. • Taste unacceptable to some users. • Requires the continual purchase of chlorine.

PuR - Combined Coagulant and Disinfectant

Proctor and Gamble Health Sciences Institute developed the PuR water treatment product, which is composed of coagulants and chlorine. When mixed with water, it coagulates and speeds up the settlement of solid particles while disinfecting the water. The water is then strained or decanted to remove the suspended particles.

The product is promoted as an affordable and simple-to-use household water purification product. It clarifies the water and effectively reduces microbial pathogens.

Advantages	Disadvantages
• Some removal of microbial, chemical, and physical contaminants. • Current price of about $US 0.01 per litre of treated water.	• Requires outside supply of chemicals. • Educational efforts including product demonstrations are necessary to encourage a consumer habit change. • Requires a 20 minute wait time.

Solar Water Disinfection (SODIS)

SODIS is a simple water treatment method using solar radiation (UV-A light and temperature) to destroy pathogenic bacteria and viruses in the water. Its efficiency in killing protozoa depends upon the water temperature reached during solar exposure and on the climatic and weather conditions. Microbial contaminated water is poured into transparent containers and exposed to full sunlight for a minimum of six hours. Various types of transparent plastic materials are good transmitters of light in the UV and visible range of the solar spectrum.

Plastic bottles made from PET (PolyEthylene Terephtalate) are preferred because they contain fewer UV-stabilizers than PVC (PolyVinylChloride) bottles. Glass bottles can also be used for SODIS.

Water with a turbidity of more than 30 NTU cannot be used for SODIS. Sunlight treats the contaminated water through two synergetic mechanisms: radiation in the spectrum of UV-A (wavelength 320-400nm) and increased water temperature. If the water temperature rises above 50°C, the disinfection process is three times faster.

Advantages	Disadvantages
• Kills most biological contaminants. • Relies on local resources and renewable energy. • Ideal to treat small quantities of water. • Costs are minimal; the system only requires plastic bottles, which can be reused. • Simple and affordable.	• Does not remove chemical contaminants or turbidity. • Does not improve taste or odour of the water. • The container needs to be exposed to the sun for six hours if the sky is clear or up to 50% cloudy. • The container needs to be exposed to the sun for two consecutive days if the sky is 100% cloudy. • During days of continuous rainfall, SODIS does not perform. • SODIS is not useful for treating large quantities of water.

Source: SANDEC (Water & Sanitation in Developing Countries) at EAWAG (Swiss Federal Institute for Environmental Science and Technology), CH-8600 Dübendorf, Switzerland.

Water Pasteurization

Pasteurization is the process of disinfecting water by heat or radiation. Water pasteurization achieves the same effect as boiling, but at a lower temperature of 70-75° C. A simple method of pasteurizing water is to simply put blackened containers of water in a solar box cooker, an insulator box made of wood, cardboard, plastic, or woven straw. Common solar box cookers can pasteurize water at a rate of about 1 litre per hour.

A thermometer or indicator is needed to tell when the pasteurization temperature is reached regardless of the type of solar cooker. Solar Cookers International's reusable Water Pasteurization Indicator (WAPI) is a simple device that contains a special soy wax that melts after the water has been pasteurized (Solar Cookers International, nd).

Safe Water Systems also manufactures Solar Water Pasteurizer household units that disinfect water by combining heat pasteurization with UV radiation (Safe Water Systems, nd).

Advantages	Disadvantages
• Removes over 99% of the bacteria, viruses, helminths, and protozoa. • Can be built with local materials or purchased commercially.	• Does not remove salts, chemicals, or turbidity. • Weather dependant.

UV Disinfection

The use of ultraviolet light to disinfect water is not a new technology. However, the availability of small scale, energy efficient, affordable and low-maintenance devices is a recent development.

The UV light interferes with the DNA of the micro-organisms in the water, rendering them incapable of replication. A typical unit will treat 5 litres/minute, which can supply sufficient treated water for between 200 and 500 people. UV disinfection offers the first practical means of providing many communities in developing nations with adequate quantities of disinfected drinking water.

Advantages	Disadvantages
• Effective on all water-borne bacteria and diseases. • Disinfects quickly at about five minutes per litre.	• No chemical or physical contaminant removal. • Initial costs: \$50-\$150 US. • Operating costs: \$10-\$25 US per year for bulb replacement. • Requires electricity. • Does not improve taste or odour.

Boiling Water

Boiling water kills viral, parasitic and bacterial pathogens. The recommended boiling time is not defined in minutes but rather as the amount of time necessary to reach the first bubbling point.

The main disadvantage of boiling water is the large amount of energy required, making it economically and environmentally unsustainable.

Advantages	Disadvantages
• Kills all biological contaminants. • Simple and widely accepted. • Locally available.	• Does not remove suspended solids or dissolved compounds. • High costs for fuel. • Contributes to indoor air pollution and deforestation.

Comparison Based on a Broad Range of Household Water Treatment Technologies

Technology Types		Biological Removal	Turbidity Removal	Amount of Water		Cost ($US)	Ease of Use	
				Flow rate	Lifespan	Unit	Set-up	Maintenance
Moringa Seeds		Y	Y	N/A	Variable	$ 0	Easy	N/A
Sari Cloth		Y	Y	Variable	Limited	$ 0	Easy	None
Sand Filter		Y	Y	200 L/day	Variable	$50	Easy	Weekly
Biosand Filter		Y	Y	36 L/hr	Indefinite	$12-$30	Easy	Sporadic
Ceramic Filter	Disk	Y	Y	1-10 L/hr	5 years	$3.5	Easy	Monthly
	Candle	Y	Y	1 L/hr	6-12 mths	$2.25	Easy	Monthly
Chemical	SHS*	Y	N	N/A	Variable	Variable	Easy	None
	PUR	Y	Y	10 L/pack.	N/A	10 c/pack.	Easy	None
UV Radiation	SODIS	Y	N	1 L/bottle	1-2 years	$0	Easy	Regularly
	Lamps	Y	N	> 1 L/min	1 yr/bulb	$ 10 - $100	Mod.	Regularly

Source: jalmandir.com; cawst.org

HWT – Advantages & Disadvantages

In many parts of the world, the individual household is often responsible for treating its own drinking water. Where community utility water treatment and distribution systems do not exist, it is frequently the only viable option to treat drinking water.

Advantages	Disadvantages
Relatively cheap.	Need for knowledge and capacity for operation and maintenance.
Fast implementation.	Need to motivate users to operate and maintain correctly.
Appropriate for treating small volumes of water.	Most technologies cannot remove chemical contamination.
Creates an entry-point for hygiene and sanitation improvements.	

References

- Classen, T. (2007). Household Water Treatment Using Sodium Dichloroisocyanurate (NaDCC) Tablets: A Randomized, Controlled Trial to Assess Microbiological Effectiveness in Bangladesh. American Journal of Tropical Medicine and Hygiene.
- Fewtrell L et al. (2005). Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. Lancet Infect Dis 5: 45-52
- Instituto Eco–Engenho is a Non Governmental Organization. http://www.ecoengenho.org.br/noticias/VisualizarConteudo.asp?CodConteudoConexao=800&Codpasta=149
- Potters for Peace. pottersforpeace.org
- SANDEC (Water & Sanitation in Developing Countries) at EAWAG (Swiss Federal Institute for Environmental Science and Technology), CH-8600 Dübendorf, Switzerland., sodis.ch
- WHO-http://www.who.int/water_sanitation_health/hygiene/emergencies/em2002chap7.pdf