POINT-OF-USE WATER TREATMENT FOR HOME AND TRAVEL

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Summary

This chapter briefly describes several treatment approaches that are available for producing small quantities of water and very small treatment systems available to residential consumers and travelers to improve the quality and safety of their drinking water, whether as household or small community systems or as bottled water. There are basic treatment systems that are accessible for individuals and small communities in both developed and developing countries. For producing very small amounts of water, some of these approaches like boiling and use of chlorine as hypochlorous acid/hypochlorite or iodine are simple, inexpensive and very effective ways of treating water to kill (inactivate) or physically remove pathogenic microorganisms that can cause debilitating or even fatal waterborne disease. They should always be used by both residents and travelers in areas where the safety of the local drinking water is uncertain or unreliable. Bottled water and other water-based drinks also have widespread application, if it is certain that they are safe, e.g. that the bottled water has been

produced under sanitary conditions from safe water and is certified by a trusted entity. Simple and sometimes locally made ceramic and small sand filters can also provide some improvements in water quality by removing organisms that are retained by the filtering system, which is dependent upon its pore size.

More sophisticated and expensive devices are produced and marketed for addressing a wide range of water treatment problems. Some (POE) have the capacity to treat all of the water in the home; others (POU) can treat water that is used for drinking and cooking. All treatment systems are designed for a specific purpose, thus, it is important to select the specific type of device that is intended for the particular water quality problem or situation that is encountered. It is also most desirable to use devices that have been tested and certified by a qualified independent organization against an appropriate performance standard and demonstrated to meet all of it requirements. Finally, regular and appropriate operation and maintenance should be performed with any system according to the manufacturer's directions to assure that the unit is performing as claimed and as the consumer or community expects. In addition to safe drinking water, basic sanitation and hand washing provide significantly reduced risks of gastrointestinal disease from the same pathogens found in contaminated water.

1. Introduction

The traditional ideal solution to drinking water quantity, quality and safety problems has been centrally supplied treated water and an intact and high quality piped distribution network, supported by appropriate monitoring, water analysis and qualified management. Results of this ideal approach have been mixed especially in developing countries due to high initial costs for installation, operation and maintenance, inadequate access to training, management and finance sufficient to support a complex system and achieve consistently good quality water. Even in developed countries, centrally supplied water that is usually safe to drink may have undesirable taste, appearance, corrosivity or hardness because the cost of additional treatment might be unacceptable to the community, or the process might be too complex, especially in a small community. Water drawn from residential wells often requires some treatment to improve its safety and quality, and this becomes the responsibility of the homeowner. Travelers in areas where water is microbiologically unsafe or of uncertain safety can also take measures to avoid waterborne disease. We will not cover all water quality and treatment circumstances in this chapter, but we will address some of the most common concerns faced by small communities and individuals, both residents and travelers, and some of the effective and accessible technical and personal approaches that they can use to improve the quality and safety of their drinking water. The bibliography includes additional information on treatment technology suitable for small applications and on chemicals and devices that are available.

Convenient, easily applied, cost-effective and practical solutions should be used that can be rapidly implemented. Some of these options could involve:

- small package central treatment coupled with piped distribution, or non-piped distribution, e.g. community supplied bottled water;
- decentralized treatment for the home using basic media filtration, adsorption,

membranes and/or chemical or physical disinfection;
- further treatment in the home to deal with organic chemical contaminants and natural inorganics like fluoride or arsenic, or microbes;
- supplemental treatment to deal with aesthetic (taste, odor, color, sediment) water quality problems

These sometimes very simple and inexpensive choices as well as the more sophisticated and more expensive technological options, coupled with training, technical support and other essential elements like community commitment, provide opportunities that should be considered in individual homes and for rural small communities, and in rapidly growing peri-urban areas in developing counties.

2. Potential Solutions for Small Communities

In developing countries, especially, basic filtration and disinfection provide immediate and obvious public health benefits at the least cost. The water treatment emphasis in small communities should be on low-tech treatment technologies which require minimal capital costs, and which maximize use of local resources such as community labor and materials and renewable energy. When one takes into consideration all potential problems those small systems could face, defining practical technology should include at least the following components:

- a technology that does not require imported chemicals or replacement parts (locally available or none);
- a technology that is simple, rugged, user-friendly, economically sustainable, and easy to maintain at the local level;
- a system acceptable to the community so that they understand how to use it, and are willing to maintain it;
- consideration should be given to utilization of “circuit riders” (regional technical specialists) who can provide services to a number of small water systems in a region when more sophisticated technologies are used.

For any small community water system the specific application will vary; however the technology should be customized to the site’s needs and local resources that are available to sustain water service over the long term. Finding a solution for wealthier communities is less challenging as they have more technological options available and at least the potential for paying costs, obtaining external support and funding and obtaining outside technical assistance.

As developing countries face more challenges and because their options are more limited, they should focus on practical and more manageable goals. Instead of trying to provide water of highest quality for all needs, the initial focus should perhaps shift to producing sufficient microbiologically safe water for direct consumption as the critical need, as opposed to large quantities for all uses. In that case, simple, low-tech and practical technologies and non-piped drinking water distribution would be more applicable in those communities. Thus, some recommended options for developing countries could include central production of water and centralized or decentralized distribution e.g. bottled water; and/or individual water production using proven point-of-use treatment. Some of these options are discussed below.

2.1. Package Treatment Plants

Package treatment plants are attractive alternatives because they are premanufactured off-the-shelf technologies that can be customized to fit the site specifications. Typically they have been applied to piped distribution systems, however, they can also be used to produce quantities of safe bottled water. They can incorporate a broad range of treatment technologies, including filtration, carbon adsorption, reverse osmosis, other levels of membrane filtration, chlorination, ozonation and ultraviolet irradiation. Appropriate treatment will depend on the condition of the source water, site characteristics, as well as the system size and maintenance needs. The costs will depend on the choice of treatment technologies, system sizing, ongoing maintenance requirements, and integration with site infrastructure. These package plants are widely used in developed countries, and there are examples in developing counties where they have been applied successfully. They were successful because the systems were properly designed, sized and applied to address the site-specific conditions presented in each location and easily maintained and repaired using locally available materials.

2.2. Slow-Sand Filtration (SSF)

Slow-sand filtration is another treatment technology for central production of high quality water. It is an old technology that is relatively low tech and has been proven to be effective. The process involves passing water slowly through a filter bed or media (normally native sand of the correct size) allowing physical, chemical and biological processes to treat the water. If the system is well designed, operated and maintained, it will produce drinking water of good quality. Although the removal mechanisms may be complex, the basic components are simple. They are: 1) filter box, 2) filter media to include sand, the support gravel and underdrain collection system, and 3) a flow control system. This simple technology can fit small and large scenarios and is easy to operate and maintain. Engineering design and operation variables include, filter media source, size specification and depth, filtration rate, raw water source characteristics, pre-clarification, algae and animal (worms and insect larvae) control and need for filter cover. Small, intermittently operated (batch pour-through) slow sand filters, called “biosand” filters, are also available to produce sufficient water on demand for use by one or a small cluster of households or for schools, health care and other facilities.

Although slow sand filtration is recognized as an effective, single unit treatment process, its efficiency can be challenged by water sources that are extremely turbid and contaminated. This relates to high quantities of suspended solids, high fecal microbe counts and large quantities of algae. Therefore, conditions that inhibit or reduce the efficiency of the treatment process should be avoided. The use of sedimentation or coarse gravel prefiltration is suggested prior to the application of slow sand filter technology for more contaminated water. For the most part, the SSF technology produces water low in turbidity, largely free of impurities and more importantly virtually free of bacteria, enteric viruses and protozoa. SSF treatment can be followed by disinfection for greater assurance of microbiological quality and effective control of post-treatment contamination during storage and distribution.

2.3. Roughing and Horizontal Flow Granular Media Filters

Simple, low cost, low-maintenance, multi-stage roughing filters for household and community use have been described and characterized Typically, they are rectangular, multi-compartment basins constructed of concrete or other materials. They require modest skills for operation and maintenance, and therefore, are best suited for use by communities or at least multiple households. However, it is possible for these multi-compartment tanks to be centrally fabricated and distributed at low cost for placement and final installation at their locations of use. Roughing filters usually consist of differently sized granular filter material decreasing successively in size in the direction of flow. Many are designed to use two different sizes of low cost, coarse granular media in two or three compartments or stages, and such media are generally locally available.

Most of the solids in raw water are separated by the coarse filter medium near the filter inlet, with additional removal by the subsequent medium and fine granular media in subsequent compartments. In a typical design, water flows horizontally (or vertically in either an up-flow or down-flow mode) into an initial chamber containing fine gravel or coarse sand and then into another chamber or (two successive chambers) containing coarse or medium sand having smaller particle sizes than the initial chambers and from which it then discharges as product water. For highly turbid water containing settleable solids, a horizontal or vertical sedimentation basin to remove this coarse material prior to filtration precedes the filter. The filter has provision for backwashing the medium from a valved inlet (at the bottom of the filter medium chamber in the horizontal and down-low filter designs).

Roughing filters are operated at relatively low hydraulic loads or flow rates. Regular backwashing is required to main flow rates and achieve efficient particulate removals, and therefore, some skill and knowledge is required to properly operate and maintain a roughing filter. Removal of fecal indicator bacteria by roughing filters has been reported to be 90-99%. Although not reported in the available literature, it is expected that compared to bacteria removals, virus removals would be lower and parasite removals would be similar or higher. Because microbial removal is only moderate, it is recommended that the filtered water be further treated by free chlorine or other chemical disinfection to further reduce pathogens and provide a protective disinfectant residual during distribution, storage and use.

Most roughing filters are too large for individual household use. They also require skillful operating conditions and maintenance procedures, such as backwashing or hydraulic scouring with large volumes of water. These operation and maintenance procedures are probably too complex for use at the individual household level. Therefore, these filters are best applied at the community level where they can be managed by trained personnel and serve the needs of multiple users or the whole community.

3. Point-of-Use and Personal Water Treatment

Water can be treated or re-treated in the home in small quantities to significantly improve its quality and safety. The simplest and most important effective treatments of microbiologically contaminated water are disinfection and filtration to remove or inactivate pathogenic microorganisms. Numerous simple treatment approaches and commercially available technologies are also available to treat drinking water for single person use as by a traveler and also in the home.

3.1. Microbiologically Safe Water for Travelers

Numerous organizations including the World Health Organization and the U.S. Centers for Disease Control and Prevention have prepared guidance on safe drinking water for residents and travelers in areas with drinking water that is suspected of being unsafe or of uncertain safety. Many of these simple methods are also valid for routine application by residents in regions with microbiologically unsafe or questionable water, and also during emergency situations when normal water supplies have been compromised or people have become displaced or relocated.

3.1.1. Preventive Measures While Living or Traveling in Areas with Unsafe Drinking Water

- Drink water that you have boiled, filtered and/or treated with chlorine or iodine and have stored in clean, protected containers; consume ice **only** if it is known to be of drinking water quality.
- Drink bottled water or other commercial beverages (carbonated beverages, juices and pasteurized milk) provided in sealed tamper-proof containers and bottled/canned by known brands (preferably certified by responsible authorities). Hotel personnel or local hosts are often good sources of information about which local brands are safe.
- Hot beverages such as coffee and tea are often made with boiled or heated water and are therefore usually safe if kept hot and stored in clean containers. Other beverages should be made with safe water (as described later below).
- Always avoid consumption or use of unsafe water (even when brushing teeth) if you are unsure about water quality. Water that looks clear should not be assumed to be free of contaminants and safe.
- Avoid consumption of homemade or non-commercial unpasteurized juices.
- Consume ice only if it is known to be of drinking-water quality and not handled by bare hands.
- Avoid salads or other uncooked dishes that may have been washed or prepared with unsafe water.
- Peel fruit prior to consumption.

3.1.2. Drinking Water Disinfection Techniques for Small Quantities

BOILING: Bringing water to a visibly **ROLLING BOIL** is the most effective way to kill almost all disease causing pathogens even at high altitudes (e.g. less than about 6600 feet or 2 km). It need not be retained at boiling for any extended period of time. Let the hot water cool down on its own without adding ice. If the water is clear, no other treatment is needed if the water has been boiled. Protecting the water from recontamination after boiling and during use is essential.

FILTRATION: If water is turbid (not clear, or with suspended solid matter), it should be clarified before disinfection; clarification includes filtration, settling and decanting. Portable treatment devices that have been tested and rated to remove protozoa and some bacteria are also available; ceramic filters and some carbon block filters are the most common types. The filter's pore size rating must be 1 micron (absolute) or less to ensure removal of *Cryptosporidium* oocysts; however such filters do not remove all bacteria or most viruses (These very fine filters must be pressurized and also may require a prefilter to remove larger particles to avoid clogging the final filter). A combination of technologies (filtration followed by chemical disinfection or boiling) is recommended since most filtering devices neither remove nor kill viruses.

CHEMICAL DISINFECTION: Chemical disinfection e.g. with free chlorine is effective for killing bacteria and viruses and some protozoa (but not *Cryptosporidium* oocysts and probably not C*yclospora*). The water should be clear before application of the disinfectant chemical. Some form of free chlorine (e.g. bleach or sodium hypochlorite, calcium hypochlorite, dichloroisocyanuric acid), iodine and chlorine dioxide (acid activated at time of use from sodium chlorate or chlorite solution) are the chemicals most widely used for disinfection.

Often, after chemical treatment, a granular carbon (charcoal) filter is used to improve taste, and in the case of iodine treatment to remove excess iodine. Note that silver is not very effective for eliminating disease causing microorganisms. Silver by itself is slow acting and principally used to prevent bacteria growth on filter media, but it is not able to disinfect (inactivate) all classes of pathogens in the water. Chlorine dioxide produced at point-of-use by adding acid to a chlorite or chlorate salt solution is recommended only for short-term use (e.g, by travelers, during outdoor recreation and in emergencies) due to the potentially high levels of chlorate or chlorite present in the treated water

SOLAR DISINFECTION: Solar exposure of sufficient intensity for a sufficient time can achieve disinfection or pasteurization of a small amount of water. The SODIS system consists of placing low turbidity water (< 30 NTU) into a clean clear plastic bottle of about 1-2 liters, aerating the water by vigorous shaking, exposure to full sunlight for about 5 hours, or longer if there is only part sunlight. The bottles can be glass, PET (preferred) or PVC beverage bottles, and heat buildup will increase if they are on a dark, opaque surface. The UV and heating achieve good inactivation of bacteria, viruses, and protozoa. Water temperatures can easily exceed 60 degrees C.

Completely black bottles or pots (e.g., metal cooking pots) will also achieve pasteurization if at sufficiently high temperature (>63 degrees C) for only tens of minutes. When using opaque containers, the use of simple solar reflectors that direct additional sunlight onto the container speed up the process and can further increase the temperature. These are the same principals and practices that are used in solar cooking. Temperatures of about 65 C for several tens of minutes achieve pasteurization that will inactivate nearly all enteric pathogens. To monitor temperature a thermometer, thermally sensitive tape or paint that changes color or a simple wax indicator device that melts at the desired target temperature can all be used to indicate and assure that the desired temperature is reached.

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Biographical Sketches

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