8.4.14 Household water treatment technologies

Household water treatment and storage (HWT) technologies are any of a range of devices or methods employed for the purposes of treating water in the home or at point of use in other settings. These are also known as point-of-use (POU) or point-of-entry (POE) water treatment technologies (Cotruvo & Sobsey, 2006). HWT technologies comprise a range of options that enable individuals and communities to treat collected water to remove or inactivate microbial pathogens. There are also many devices marketed that will remove chemical and radiological contaminants, although usually that is not the major focus of HWT aimed at microbial contamination. HWT technology has the potential to fill the service gap where piped water systems are not possible, resulting in enormous positive health impacts in developing countries as a barrier to waterborne infectious disease due to source water contamination (e.g., home wells, cisterns or surface waters). Many piped water supplies are also microbiologically unsafe due to post-collection and post-treatment contamination during distribution, and HWT technologies can also be used to overcome this widespread problem. Similar small technologies can also be used by travellers in areas where the drinking-water quality is uncertain.

Definitions and descriptions of the various HWT technologies follow:

- **Chemical disinfection**: Drinking-water chemical disinfection includes any chlorine- or iodine-based technologies, including chlorine dioxide, as well as ozone, some other oxidants and some strong acids and bases. Chemical disinfection is most widely done with technologies using free chlorine (hypochlorous acid) and, to lesser extents, with di- and trichlorocyanurates of free chlorine, chloramines, chlorine dioxide or other forms of chlorine oxidants. The chlorine and iodine technologies as well as ozone all share similar mechanistic features based on the oxidizing properties of these compounds. Except for ozone, all of these disinfectants provide the additional benefit of leaving a residual in the water that provides some protection from post-microbial contamination during storage. Disinfection of household drinking-water in developing countries is done primarily with free chlorine, commonly available as chlorine bleach. This is because it is quite effective, widely available and used globally, easy to dose and inexpensive. Disinfection of drinking-water with iodine, which is also a strong oxidant, is generally not recommended for extended use unless the residual concentrations are controlled. This is because there are concerns about adverse effects of excess intake on the thyroid gland; however, dietary iodine deficiency is a more serious health problem in many parts of the world. Iodine is used in emergency or other short-term interventions where other options are not indicated. Iodine can be delivered to water through several means, including aqueous solutions, tablets or iodinated synthetic polymer resins that slowly release active iodine. Tetraglycine hydroperiodide tablets that liberate free iodine in water have been widely used in field military and recreational settings. Ozone is not recommended for household water treatment because of its cost and complexity of generation in a small application. Strong acids or bases are not recommended as chemical disinfectants for drinking-water, as they are hazardous chemicals that can alter the pH of the water to dangerously low or high levels. However, as an emergency or short-term intervention, the juices of some citrus fruits, such as limes and lemons, can be added to water to
inactivate *Vibrio cholerae* bacteria, if enough is added to sufficiently lower the pH of the water (probably to pH less than 4.5) (Sobsey, 2002).

- **Membrane, porous ceramic or composite filters**: These are filters with defined pore sizes and include carbon block filters, porous ceramics containing colloidal silver, reactive membranes, polymeric membranes and fibre/cloth filters. They rely on physical straining through a single porous surface or multiple surfaces having structured pores to physically remove and retain microbes by size exclusion. Some of these filters may also employ chemically active antimicrobial or bacteriostatic surfaces or chemical modifications to cause microbes to become adsorbed to filter media surfaces, to be inactivated or at least to not multiply. Cloth filters, such as those of sari cloth, have been recommended for reducing *Vibrio cholerae* in water. However, these filters only reduce vibrios associated with copepods, other large crustaceans or other large eukaryotes retained by the cloth. These cloths will not retain dispersed vibrios or other bacteria not associated with copepods, other crustaceans, suspended sediment or large eukaryotes because the pores of the cloth fabric are much larger than the bacteria, allowing them to pass through.

- **Granular media filters**: Granular media filters include those containing sand, diatomaceous earth or others using discrete particles as packed beds or layers of surfaces over or through which water is passed. These filters retain microbes by a combination of physical and chemical processes, including physical straining, sedimentation and adsorption. Some may also employ chemically active antimicrobial or bacteriostatic surfaces or other chemical modifications. Other granular media filters are biologically active because they develop layers of microbes and their associated exopolymers on the surface of or within the granular medium matrix. This biologically active layer, called the *schmutzdecke* in conventional slow sand filters, retains microbes and often leads to their inactivation and biodegradation. A household-scale filter with a biologically active surface layer and that can be dosed intermittently with water has been developed called the Biosand filter.

- **Solar disinfection**: There are a number of technologies using solar irradiation to disinfect water. Some use solar radiation to inactivate microbes in either dark or opaque containers by relying on heat from sunlight energy. Others, such as the SODIS system, use clear plastic containers penetrated by UV radiation from sunlight that rely on the combined action of the UV radiation, oxidative activity associated with dissolved oxygen and heat. Other physical forms of solar radiation exposure systems also employ combinations of these solar radiation effects in other types of containers, such as UV-penetrable plastic bags (e.g., the “solar puddle”) and panels, to improve the microbiological quality of water.

- **UV light technologies using lamps**: A number of drinking-water treatment technologies employ UV light radiation from UV lamps to inactivate microbes. For household- or small-scale water treatment, most employ low-pressure mercury arc lamps producing monochromatic UV radiation at a germicidal wavelength of 254 nm. Typically, these technologies allow water in a vessel or in flow-through reactors to be
exposed to the UV radiation from the UV lamps at sufficient dose (fluence) to inactivate waterborne pathogens. These may have limited application in developing country environments due to the need for a reliable supply of electricity, cost and maintenance requirements.

- **Thermal (heat) technologies**: Thermal technologies are those whose primary mechanism for the destruction of microbes in water is heat produced by burning fuel. This includes boiling and heating to pasteurization temperatures (typically >63°C for 30 min when applied to milk). The recommended procedure for the former is to raise the temperature so that a rolling boil is achieved, removing from heat and allowing the water to cool naturally and then protecting it from post-contamination during storage due to lack of any residual disinfectant. The previously mentioned solar technologies using solar radiation for heat or for a combination of heat and UV radiation from sunlight are distinguished from this category.

- **Coagulation, precipitation and/or sedimentation**: Coagulation or precipitation is any device or method employing a natural or chemical coagulant or precipitant to coagulate or precipitate suspended particles, including microbes, to enhance their sedimentation. Sedimentation is any method for water treatment using the settling of suspended particles, including microbes, to remove them from the water. These methods may be used along with cloth or fibre media for a straining step to remove the floc (the large coagulated or precipitated particles that form in the water). This category includes simple sedimentation, or that achieved without the use of a chemical coagulant. This method often employs a series of three pots or other water storage vessels in series, in which sedimented (settled) water is carefully transferred by decanting daily so that by the third vessel, the water has been sequentially settled and stored a total of at least 2 days to reduce microbes.

- **Combination (multi-barrier) treatment approaches**: These are any combination of the above technologies used together, either simultaneously or sequentially, for water treatment. These could be combinations or multiple barriers such as coagulation/disinfection, media filtration/disinfection or media filtration/membrane filtration. Some combination systems are commercial products in the form of granules, powders or tablets containing a chemical coagulant such as an iron or aluminium salt and a disinfectant such as chlorine. When added to water, these chemicals coagulate and flocculate impurities to promote their rapid and efficient sedimentation and also deliver the chemical disinfectant (e.g., chlorine) to inactivate microbes. To use these combined coagulant/floculant/disinfectant products, they are added to specified volumes of water, allowed to react for floc formation, usually with brief mixing to promote coagulation-flocculation, then allowed to remain unmixed for the floc to settle, and the clarified supernatant water is decanted off, usually through a cloth or other fine-mesh medium to strain out remaining particles. The recovered supernatant is stored for some period of time, typically several tens of minutes, to allow for additional chemical disinfection before use.
**HWT technologies for chemical contamination**

The chemicals of greatest health concern in some natural waters are usually excess fluoride, nitrate/nitrite and arsenic. Their removal technologies are usually more complex and more expensive than those required for microbial control. There are numerous commercial water treatment technologies available for small applications for removal of chemical contaminants. For example, anion exchange using activated alumina or iron-containing products will effectively reduce excess fluoride concentrations. Bone char has also been used to reduce fluoride. Arsenic is also removed by anion exchange processes similar to those employed for fluoride. Nitrates and nitrates, which are frequently present due to sewage contamination or agricultural runoff, are best managed by protecting the source water from contamination. They are difficult to remove, although disinfection will oxidize nitrite to nitrate, which is beneficial, because nitrite is the more toxic form. In addition, disinfection will sanitize the water and reduce the risk of gastrointestinal infection, which is a factor in the risk of methaemoglobinemia caused by excess nitrate/nitrite exposure of infants up to approximately 3–6 months of age. Synthetic and natural organic chemicals can be removed by GAC or carbon block technologies. They must be well managed and replaced regularly because their effectiveness is eventually lost, depending upon the types of contaminating chemicals and their concentrations in the water. Reverse osmosis technologies have general applicability for removal of most organic and inorganic chemicals; however, there is some selectivity, and also there is a significant amount of water wastage when low-pressure units are used in small volume applications.

**Additional citations to be added to reference list:**
