Review Article

Household Water Purification: Low-Cost Interventions

Col VK Agrawal (Retd)*, **Brig R Bhalwar+**

Abstract

Numerous studies have shown that improving the microbiological quality of household water by point-of-use treatment reduces diarrhoea and other waterborne diseases. The most promising and accessible of the technologies for household water treatment are filtration with ceramic filters, chlorination with storage in an improvised vessel, solar disinfection in clear bottles by the combined action of UV radiation and heat, thermal disinfection (pasteurization) in opaque vessels with sunlight from solar cookers or reflectors and combination systems employing chemical coagulation-flocculation, sedimentation, filtration and chlorination. However each of these technologies have limitations and effectiveness can be increased by use of two or more treatment systems in succession for improved treatment and the creation of multiple barriers. In particular those treatments that provide no residual disinfectant, such as boiling, solar treatment, UV disinfection with lamps and filtration could be followed by chlorination to provide a multibarrier approach. Water purifiers based on multiple interventions such as filtration/ultra filtration/ activated carbon adsorption / UV rays disinfection are available in the market which can be used to purify the water at point of use. Water purifiers based on single interventions like candle filters, resins filters or ultraviolet lamp can be used in most places being supplied water after purification. Troops on operational move can purify water by fabric/resins filtration and chlorine disinfection or by flocculent-disinfectant.

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Key Words : Household water purification; Low-cost interventions; Effectiveness

Introduction

It has been estimated that 1.1 billion people do not have access to improved drinking water sources [1]. Consumption of unsafe water continues to be one of the major causes of the 2.2 million diarrhoeal disease deaths occurring annually, mostly in children [2]. There is now conclusive evidence that simple, acceptable, low-cost interventions at the household and community level are capable of dramatically improving the microbial quality of household stored water and reducing the risks of diarrheal disease [3-5]. In this review the candidate technologies and approaches for household water treatment are examined on the basis of their technical feasibility, practicality, availability and effectiveness in improving the microbiological quality of water and reducing waterborne disease.

Boiling

Boiling or heating of water is effective in destroying all classes of waterborne pathogens and can be effectively applied to all waters, including those high in turbidity. Although boiling is the preferred thermal treatment for contaminated water, heating to pasteurization temperatures (60^{o}C) for tens minutes will destroy most waterborne pathogens. Even heating to as little as 55^{o}C for several hours has been shown to dramatically reduce non-spore forming bacterial pathogens as well as many viruses and parasites, including the waterborne Cryptosporidium parvum, Giardia lamblia and Entamoeba histolytica [6].

Thermal Treatment with Solar Radiation

Water can be heated to temperatures of 55^{o}C in transparent bottles exposed to sunlight for several hours, especially if the bottle is painted black on one side or is lying on a dark surface that collects and radiates heat [7]. This method of treatment utilizes both the UV radiation in sunlight as well as the thermal effects of sunlight to inactivate waterborne microbes. A major limitation of solar heating is the availability of sunlight, which varies greatly with season and geographic location. Another potential limitation of solar heating to disinfect water is the determination of water temperature. Several simple, low cost temperature indicators have been devised. One of the simplest and most effective is a reusable water pasteurization indicator based on the melting temperature of soyabean wax.

Solar Treatment by UV and Thermal Effects

Treatment to control waterborne microbial contaminants by exposure to sunlight in clear vessels that allows the combined germicidal effects of both UV

*Prof (PSM), Rohilkhand Medical College, Pilibhit Bypass Road, Bareilly-243006. +Consultant (PSM), Army Hosp (R&R), Delhi Cantt-10
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radiation and heat also has been developed, evaluated and put into field practice [8,9]. A number of different solar treatment systems have been described, but one of the technically simplest and most economical is the SODIS system. The SODIS system consists of four basic steps; removing solids from highly turbid (>30 NTU) water by settling or filtration, placing low turbidity (<30 NTU) water in clear plastic bottles, aerating the water by vigorous shaking in contact with air and exposing the filled, aerated bottles to full sunlight for about five hours or longer if only part sunlight. There was a measurable reduction in diarrheal disease and cholera in Kenyan children drinking solar disinfected water [10].

UV Disinfection using Lamps

Disinfection of drinking water with UV lamps has been practiced since the early part of the 20th century [11]. This method of drinking water disinfection has received renewed interest in recent years because of its well-documented ability to extensively (>99.9%) inactivate two waterborne, chlorine-resistant protozoans, Cryptosporidium parvum oocysts and Giardia lamblia cysts. However, dissolved organic matter and suspended matter absorb UV radiation or shield microbes from UV radiation, resulting in lower delivered UV doses and reduced microbial disinfection. In addition, UV provides no residual effect in the water to protect against post-treatment contamination.

Fiber, Fabric and Membrane Filters

Most fabric and paper filters have pore sizes greater than the diameters of viruses and bacteria, so removal of these microbes is low, unless the microbes are associated with larger particles. However, some membrane and fiber filters have pore sizes small enough to efficiently remove parasites (one to several micrometers pore size), bacteria (0.1-1 micrometer pore size) and viruses (0.01 to 0.001 micrometer pore size or ultrafilters). Paper filters have been recommended for the removal of schistosomes and polyester or monofilament nylon cloth filters have been recommended for the removal of the Cyclops. Such filters have been used successfully at both the household and community levels [12]. Various types of sari cloth and nylon mesh can be used in single or multiple layers to remove from water the zooplankton and phytoplankton harboring Vibrio cholerae, thereby reducing their concentrations by >95 to >99% [13].

Porous Ceramic Filters

Most modern ceramic filters are in the form of vessels or hollow cylindrical “candles”. Water generally passes from the exterior of the candle to the inside, although some porous clay filters are designed to filter water from the inside to the outside. Many commercially produced ceramic filters are impregnated with silver to act as a bacteriostatic agent and prevent biofilm formation on the filter surface. However, all porous ceramic media filters require regular cleaning to remove accumulated material and restore normal flow rate. Porous ceramic filters can be made in various pore sizes and most modern ceramic filters produced in the developed countries of the world are rated to have micron or sub-micron pore sizes that efficiently remove bacteria as well as parasites. Ceramic filters in various countries of the developed world have been extensively tested for efficacy in reducing various waterborne microbial contaminants and some of these are rated to remove at least 99.9% of bacteria, such as Klebsiella terrigena, 99.9% of viruses, such as polioviruses and rotaviruses, and 99.9% of Giardia cysts and Cryptosporidium oocysts [14].

Alum and Iron Coagulation and Sedimentation

When potash alum was evaluated for household water treatment in a suburban community in Myanmar by adding it to water in traditional storage vessels, fecal coliform contamination was reduced by 90-98% and consumer acceptance of the treated water was high [15]. In another study, alum potash was found to be effective in reducing illness among family members in intervention households (9.6%) than in control households (17.7%) in a cholera affected area [16].

Charcoal and Activated Carbon Adsorption

Main application of charcoal and activated carbon is the reduction of toxic organic compounds as well as objectionable taste and odour compounds in the water [17]. Although fresh or virgin charcoal or activated carbon will adsorb microbes, including pathogens, from water, dissolved organic matter in the water rapidly takes up adsorption sites and the carbon rapidly develops a biofilm. In many point-of-use devices the carbon is impregnated or commingled with silver that serves as a bacteriostatic agent to reduce microbial colonization and control microbial proliferation in the product water.

Ion Exchange Disinfection

Ion exchange disinfection is primarily with iodine in the form of tri-iodide or penta-iodide exchange resins. Portable and point-of-use iodine exchange resins have been developed and extensively evaluated for inactivation of waterborne pathogens, primarily in developed countries. Most of these are in the form of pour through cups, pitchers, columns through which water is passed so that microbes come in contact with the iodine on the resin. Point-of-use iodine resins have

Table1

Comparison of household water purification interventions

Method	Availability and practicality	Cost (a)	Microbial efficacy (b)	Limitations
Boiling	Varies (c)	Depend on fuel	High	Time consuming / High cost / Recontamination / Loss of mineral
Exposure to Sunlight	High	Low	Moderate	Weather conditions / water should not be turbid
UV Irradiation (lamps)	Varies (d)	Moderate-high (d)	High	High cost/ regular maintenance/ piped water supply / Electricity is required
Plain sedimentation	High	Low	Low	Time consuming/Low efficacy
Filtration (ceramic, membrane filters)	Varies (e)	Varies	Varies	Cost/Regular cleaning of filters/Efficacy varies on size of pores of filters
Coagulation and Precipitation (e.g. Alum)	Moderate	Varies	Varies	Time consuming/Efficacy varies/Excess coagulant gives metallic taste
Adsorption (charcoal, carbon, clay, etc.)	High to moderate	Varies	Varies with adsorbent	Regular cleaning/ replacement of adsorption media at regular interval
Ion exchange (Resins with iodine e.g. Zero B)	Low to Moderate	Usually High	Low or moderate	Cost/Regular maintenance or cleaning
Chlorination	High to Moderate	Moderate	High	Less effective in turbid water
Filtration/ activated carbon adsorption/UV rays disinfection (Aquaguard by Eureka Fobres and Zero B water purifiers)	Varies	High	High	High cost/Electricity /periodic expenditure and maintenance

(a) Categories for annual household cost estimates in Rupees are less than Rupees 500 for low, >Rupees 500-5000 for moderate and >Rupees 5000 for high. (b) Categories for microbial efficacy are based on estimated order-of-magnitude or log10 reductions of waterborne microbes by the treatment technology. The categories are <1 log10 (<90%) is low, 1 to 2 log10 (90-99%) is moderate and >2 log10 (>99% is high). (c) Depends on heating method as well as cost of fuels, which range from low to high. (d) Depends on type of lamps, cost of electricity, as well as maintenance (e) Practicality, availability, cost and microbial efficacy depend on the filter medium e.g. Membrane, ceramic, fabric,

been found to extensively inactivate viruses, bacteria and protozoan parasites [18].

Chlorine Treatment

Chlorine is the most affordable, easily and widely used agent. It is highly effective against nearly all waterborne pathogens, with notable exceptions being Cryptosporidium parvum oocysts and mycobacteria species [19]. At doses of a few mg/l and contact times of about 30 minutes, free chlorine generally inactivates >4 log10 (>99.99%) of enteric bacteria and viruses. Water should be free of turbidity for effective chlorination. Advantages of chlorine treatment are that it is cheap and provides residual effect.

Combined Treatment Systems

In South Africa commercial tablets containing chlorine and aluminium sulfate have been developed, evaluated and promoted for community and household water treatment [20]. Overall, combined coagulation-flocculation and chlorine disinfection systems have shown considerable promise as microbiological purifiers of household water [21]. Water purifiers based on multiple interventions such as filtration/activated carbon adsorption / UV rays disinfection are available in the market which can be used to purify the water at point to use but they have high installation and maintenance cost.

Conclusion

Table 1 summarizes the various household technologies for water purification on the basis of their practicality, availability and effectiveness in improving the microbiological quality of the water, cost and limitations. Water purifiers based on multiple interventions such as filtration / ultra filtration / activated carbon adsorption / UV rays disinfection are available in the market which can be used to purify the water at point to use in catering establishments and individual houses if quality of water supplied to these places is not satisfactory, otherwise water purifiers based on single interventions like candle filters, resins filters (zero B suraksha) or ultraviolet lamp can be used since most of these places are being supplied water after purification by Military Engineering Services / Cantonments. Troops on operational move can purify water by chlorine disinfection (aqua tab).

Conflicts of Interest

None identified

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