

Point of Use Household Drinking Water Filtration: A Practical Effective Solution for Providing
Sustained Access to Safe Drinking Water in the Developing World

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Abstract

1.1 billion of people in developing countries do not have access to clean and purified water. The only water that is available to drink has many contaminants that can cause digestive track issues and lead to diarrheal diseases and many other life-threatening illnesses. Even those who have access to improved water supplies are still at risk for ingesting many pathogens that can cause diseases such as cholera, enteric fever, dysentery and hepatitis. Over 1.6 million people die a year from diarrheal diseases, most of those children in developing countries. Point-of-use (POU) water treatment technology has greatly impacted the homes and lives of many people in developing countries as it seeks to improve the quality of water in their homes. POU has many different technologies that have been implemented to meet their goal to improve water quality, but not all of the technologies made by POU have been properly tested for effective and sustained use.

The studies that have been done on the different POU technologies created provide guidance to show technologies supply the people needs, while also being efficient and sustainable. Sustainability is important when creating a filter because while it may work well in the lab, the question is can it be held to the same expectations long term. Key features of sustainable POU technologies are being able to create sufficient amounts of microbiologically safe water, effective for all types of contaminated water, ranging from soil to chemicals, high efficiency and little effort on the user's part, being relatively cheap so the people can afford the technology and reliable replacement parts, along with continuing effort in the lab to continue implementation of increased quality in the technologies over time. Producing sufficient quantities of purified water in a small amount of time is important so the users can have a ready

supply of clean water when they need it. The different technologies also need to be able to be used for multiple different types of contaminants and levels of polluted water. This ability makes it so all developing countries in the world can use the technology, with it not being limited to one or two locations in the world. The goal of POU is to reach all people around the world. The filters will also be pointless if the suffering villages do not use them. The filters have to be user-friendly so the people can be motivated to get their water using the filter. If the people do not use the filter, they will continue to suffer the adverse effects of the waterborne diseases.

The trials, studies, and data from the laboratory and field evidence showed that free chlorine, coagulation/chlorination, solar disinfection, ceramic filtration, and biosand filtration were effective technologies that did reduce the number of waterborne diseases and greatly improved water quality in the homes that they were implemented in. However, the positive impacts were not sustainable for long periods of time, as they only lasted for a few months. It is the goal to make these technologies sustainable so they can be used long-term in the homes and not have to be replaced every few months. So while the technologies were effective in improving water quality and decreasing the number of waterborne diseases in the area, they were not sustainable, which means more testing needs to be done. The studies showed though that ceramic filters and biosand filters could possibly overcome the sustainability obstacles, as they require a one time purchase only. They have also been shown to be able to increase the cleanliness of the water and prevent waterborne diseases. Adoption of the technologies is also an increasing issue as more testing is needed to determine what factors would motivate the public to get a filter. Just a day with unclean water puts people at high risk for diseases that could even be fatal, and the

ceramic and biosand filters have shown to be effective in eliminating the causes of the diseases from the water and making it safe to drink for those in the developing countries.

Materials and Methods

There are five main processes described in the article to separate bacteria that cause diarrheal diseases, and other pathogens from water, which can cause death: combined coagulation, chlorination, SODIS, ceramic filters, and biosand filters.

Combined Coagulation uses chlorine tablets and coagulation flocculation (the dispersion and adhesion of molecules, or particles, that have weak physical bonds) to separate the bacteria and pathogens. Particles bond together, causing bigger molecules to form, so when filtration occurs, the bigger molecules do not pass through the filter. This technique occurs before filtration to allow higher efficiency of cleansing bacterial and parasitic particles.

Chlorination is the process of adding some form of a bleach solution chemical (used for cleaning), such as sodium hypochlorite, to cleanse the water. The chlorine is added to clean water and acts as a disinfectant of the diarrheal bacteria. Side effects of this include a change in the odor, color, or taste of the water, and the inability to prevent parasitic attacks.

SODIS uses polyethylene terephthalate (PET) clear plastic bottles to transmit ultraviolet light when left in the sun for extended periods of time. Combining thermal inactivation and shaking the bottle to supply the water with oxygen, allows the water to be aerated and decrease the bactericidal effects, reducing the amount of children impacted by severe diarrhea.

Ceramic filters act as a filtration device, preventing microbes from flowing through, therefore cleansing the water. In more developed countries, ceramic candle filters are made to alter the outcome of the filtration to better suit the needs of the situation. It is used primarily to treat household water and often problems arise with the safe storage of the water after it passes through the filter.

Biosand filters possess the same purpose as ceramic filters and act as a more complex sand filter. The sand filter removes pathogens and suspended solids by using biological processes, preventing larger particles from flowing through natural filters.

Analysis

Tables

treatment process	pathogen group	baseline LRV ^{a,b}	maximum LRV ^c	factors influencing performance efficacy
porous ceramic filtration	bacteria	2	6	varies with pore size/structure, tortuosity, flow rate, filter medium composition, augmentation with silver or other chemical agents that enhance microbe inactivation or retention (7–10)
	viruses	0.5	4	
	protozoa	4	6	
biosand filtration (BSF)	bacteria	1	3	varies with filter maturity, dosing conditions, flow rate, pause time between doses, grain size, filter bed contact time, other design and operation factors; POU may differ in microbial removal from conventional SSF (11–13)
	viruses	0.5	3	
	protozoa	2	4	
SODIS	bacteria	3	5.5+	depends on water oxygenation, sunlight intensity, exposure time, temperature, turbidity, and size of vessel (depth of water) (8, 14–18)
	viruses	2	4+	
	protozoa	1	3+	
free chlorine	bacteria	3	6+	turbidity and chlorine demand reduce efficacy; concn × contact time predicts efficacy; ^d (19–21)
	viruses	3	6+	
	protozoa ^d	3	5+	
coagulation/chlorination	bacteria	7	9	possible physical removal of chlorine-resistant pathogens by coagulation-flocculation; turbidity may inhibit performance; reductions differ among viruses (22)(23)
	viruses	2–4.5	6	
	protozoa	3	5	

^a LRV: Log_{10} reduction value = $\log_{10}$ (pretreatment concn) – $\log_{10}$ (post-treatment concn). ^b Baseline LRV: LRV typically expected in actual field practice when done by relatively unskilled persons who apply the treatment to waters of varying quality and where there are minimum facilities or supporting instruments to optimize treatment conditions and practices. ^c Maximum LRV: LRV possible when treatment is optimized by skilled operators who are supported with instrumentation and other tools to maintain the highest level of performance in waters of predictable and unchanging quality. ^d Minimally effective against *Cryptosporidium parvum* oocysts.

Table 1: The estimates of baseline and maximum effectiveness of POU technologies against microbes in water is depicted above.

technology	diarrheal disease reduction estimate (95% CI)	compliance (estimates of self-reported and/or measured % user compliance)
SODIS (solar UV radiation + thermal effects)	31% (26%–37%) (5) ^a	78% compliance during study (24); however, poststudy compliance rates may drop as low as 9% (25)
free chlorine and safe storage	37% (25%–48%) (5) 29% (26) ^b	60–73% of households were self-reported users, but only approximately 30–40% of those who reported use had detectable free chlorine levels (27–29)
coagulation/chlorination	31% (18%–42%) (5) 29% (26)	usage rates may drop to as low as 10% after intervention ends (30)
ceramic filtration through candle filters	63% (51%–72%) (5)	high until filter breaks; in a trial in Bolivia, compliance was 88% over 6 months (31)
ceramic filtration through ceramic water purifiers	46% (29%–59%) (9)	dependent on filter breakage rates (9, 10)
biosand filtration	47% (21%–64%) (32)	>85% post-implementation (33, 34)

^a Summary estimates stratified by type of intervention (from a meta-analysis of drinking water quality interventions and diarrheal disease reductions). ^b Summary estimate from meta-analysis on POU chlorination (includes both free chlorine disinfection and combined coagulation-disinfection).

Table 2: The diarrheal disease reduction percentages by POU technologies in controlled studies is depicted above.

technology	quantity	quality	ease of use	cost	supply chain	overall score
free chlorine	3	1	3	3 (liquid) 2(tablets)	1	11
coagulation/chlorination	2	3	1	1	1	8
SODIS	1	1	1	3	3	9
ceramic filters	2	3	2	3	2	12
biosand filters	3	3	2	2	3	13

Table 3: The scoring of POU treatment technologies based on sustainability criteria is depicted above.

POU technology	sustainability evidence
free chlorine	Longest study lasted 20 months; attenuated effect of intervention found in longer trials (26). Assessing reasons for nonuse after a free chlorine social marketing campaign found 39% saying product was unavailable; 34% saying they could not afford it .
coagulation/chlorination	In follow-up studies, only 55% of those surveyed knew where to purchase product (30); in a separate survey, only 25% indicated willingness to pay the product's intended market price (37).
SODIS	Longest study lasted 12 months; even with high use during the study, 85% of study children also consumed non-SODIS treated drinking water during the study period (24); community use has varied from 20–80% (48).
ceramic candle filtration	Decline in use of approximately 20% after 9 months in Bolivia in the absence of replacement filters (44); susceptibility to ceramic candle breakage.
ceramic filtration - ceramic water purifiers	Filters became disused at rate of 2% per month, of which about 67% was due to breakage; susceptibility to filter pot and container faucet to breakage; mean time in use was 2 years (9).
biosand filtration	Continued filter use rates of >85% by households for up to eight years since introduction (33, 34).

Table 4: The table above depicts post-implementation household POU use and sustainability results for the different technologies.

Table 1 is relevant to the article as it shows the effectiveness of the different POU technologies. This is relevant to our project as we are trying to create an effective filtration/purification system for people in developing countries. The table helps show us the criteria that our filter should be meeting depending on which technique we choose to use. Table 2 is relevant to the article as it shows how well some of the technologies were in reducing the number of diarrheal diseases in the area in which the technology was implemented. This is relevant to our project because while we will not be able to test that ourselves, we will have an idea as to which technology performed the best when it came to reducing those diseases. Table 3

is relevant to the article because it also shows a table of the results of different technologies based on the different criteria that is desired in a good filtration system. The table ranks quantity, quality, ease of use, cost, and supply chain. These rankings pertain to our project as we can see what filter yielded the best results. We can also see what a good filter is based off of to try and base our design from. Table 4 is important to the article as it shows the last testing results of the sustainability of the different technologies. The studies typically last from a year to a year and a half to get accurate and precise results. This is important to our project because it gives us an idea about how they gathered information on the filters and how well the different ones held up over time. All of these tables will help us narrow down which type of filter we feel will be the most effective filter to make and improve.

References

Safe Water System. (2014, May 01). Retrieved September 13, 2017, from
<https://www.cdc.gov/safewater/index.html>