BioSand Filter

A biosand filter (BSF) is a point-of-use water treatment system adapted from traditional slow sand filters. Biosand filters remove pathogens and suspended solids from water through a combination of biological and physical processes that take place in a sand column covered with a biofilm. BSFs have been shown to effectively remove heavy metals, turbidity, and other contaminants such as bacteria, viruses, and protozoa.[1] BSFs also help to reduce discoloration, odor, and unpleasant taste. Studies have shown correlation between the use of BSFs and decreases in the occurrence of diarrheal disease and an increase in general health. Due to their effectiveness, ease of use, and lack of recurring costs, biosand filters are often considered appropriate technology in developing countries. It is estimated that over 200,000 BSFs are in use worldwide.

Biosand Filters implemented in Socorro, Guatemala by Engineers Without Borders from the University of Illinois: Urbana-Champaign

History

The household biosand filter was first conceptualized by Dr. David Manz in the late 1980s at the University of Calgary, Canada. The system was developed from the slow sand filter, a technology used for drinking water purification for almost 200 years. Initial lab and field tests were conducted in 1991, and the system was patented in 1993. That same year, the first BSF was implemented in Nicaragua. Subsequent developments on the filters have included circular designs using concrete and plastic housings. In 2001, Dr. Manz co-founded the Center For Affordable Water and Sanitation Technology (CAWST) as a worldwide distributor of BSFs.

Biosand filter components

Biosand filters are typically constructed from either concrete or plastic. The most widely used plans for the concrete biosand filter are produced and distributed by CAWST in Calgary. Alternatively, Hydraid Biosand Water Filter is a privately owned company that holds a license for a plastic biosand filter design. Most biosand filters consist of similar components. At the top of the filter there is a tightly fitted lid, which prevents contamination and unwanted pests from entering the filter. Below is the diffuser plate, which prevents disturbance of the biofilm when water is poured into the filter. Water then travels through the sand column which removes pathogens and suspended solids. Below the sand column is a layer of gravel that prevents sand from entering the drainage layer and clogging the outlet tube. Below the separating layer is the drainage layer, which consists of larger gravel that promotes water flow by preventing clogging near the base of the outlet tube.

Filtration process

Pathogens and suspended solids are removed through a combination of biological and physical processes that take place in the biolayer and within the sand layer. These processes include:

- **Mechanical trapping:** Suspended solids and pathogens are physically trapped in the spaces between the sand grains.
- **Predation:** Pathogens are consumed by other microorganisms in the biolayer.
- **Adsorption:** Pathogens become attached to each other, suspended solids in the water, and the sand grains.
- **Natural death:** Pathogens finish their life cycle or die because there is not enough food or oxygen for them to survive.

As was referenced earlier, different processes occur during different points in the filter running process. These can be broken down into segments of the filter running process: the pause period (idle time) and actual run of the filter.

During the run

The high water level (hydraulic head) in the inlet reservoir zone pushes the water through the diffuser and filter. The water level in the reservoir decreases as it flows evenly through the sand. The flow rate will slow down over time because there is less pressure to force the water through the filter. The inlet water contains dissolved oxygen, nutrients and contaminants. It provides the oxygen required by the microorganisms in the biofilm. Larger suspended particles and pathogens are trapped in the top of the sand and they partially plug the pore spaces between the sand grains. This also causes the flow rate to slow down.

Pause period (idle time)

Idle time typically accounts for greater than 80% of the daily cycle where upon various microbial attenuation processes are likely to be significant. In other words, most removal occurs during the point where water is in contact with the biofilm (also referred to as schmutzdecke). Unfortunately the exact processes that occur in the biofilm have not been identified and require further study.

When the standing water layer reaches the same height as the outlet tube, the flow stops. Ideally, this should be at a level that is high enough to keep the biofilm in the sand layer wet, but also allow oxygen from the air to diffuse through the standing water to the biolayer.

The pause period allows time for microorganisms in the biolayer to consume the pathogens and nutrients in the water. The flow rate through the filter is restored as they are consumed. If the pause period is too long, the biolayer will eventually consume all of the pathogens and nutrients and die off. This will reduce the removal efficiency of the filter when it is used again. The pause period should be a minimum of 1 hour after the water has stopped flowing up to a maximum of 48 hours.

Pathogens in the non-biological zone die off due to the lack of nutrients and oxygen.

Maintenance

Over time, particles will accumulate between the sand grains in the filter. Also, as more water is poured a biofilm will form along the top of the diffuser plate. Both of these occurrences cause a decrease in flow rate. Although slower flow rates generally improve water filtration due to idle time [APS1], it may become too slow for the users' convenience. If flow rate go below 0.1 litre/minute, it is recommended by CAWST to perform maintenance.

The cleaning method known as the "swirl and dump" or wet harrowing, is used to restore flow rate. To do this, about one gallon of water is added into the filter before cleaning (assuming the filter is empty). The upper layer of sand is then swirled in a circular motion. Dirty water from the swirling is dumped out and the sand is smoothed out at the top. This process is repeated until flow rate is restored.

It is also recommended to clean the diffuser plate, outlet tube, lid, and outside surfaces of the filters regularly.

Long term sustainability and efficacy of biosand filters is dependent on continued education and support from knowledgeable support personnel. Ideally this support should come from the local trained water workers embedded in the community.

Removal of contaminants

Turbidity

Results for turbidity reductions vary depending on the turbidity of the influent water. Water with high turbidity looks dirty due to sand, silt and clay floating in the water. Feed turbidity in one study ranged from 1.86 to 3.9 NTU. In a study water was obtained from sample taps of water treatment plants from three local reservoirs. It poured through a slow sand filter and results showed that turbidity decreased to a mean of 1.45 NTU. In another study using surface water a 93% reduction in turbidity was observed. As the biofilm above the sand ripens turbidity removal increases. Although biosand filters do exhibit a high reduction in turbidity, slow sand filters show higher removals due to a slower filtration rate.

Heavy metals

There is limited research on removal of heavy metals by biosand filters. In a study conducted in South Africa, the filter was found to have about 64% removal of iron and 5% removal of magnesium.[]

Bacteria

In laboratory studies, the biosand filter has been found to have about a 98-99% removal of bacteria. Over a time period of about two months it was found that the biosand filter may increase in the removal for *Escherichia coli* due to biofilm formation. The removal after this time period ranged from 97-99.99% removal depending on the daily charge volume and percent feed water amended with primary effluent to the filter daily. The addition of primary effluent or waste water facilitates the growth of the biolfilm which aids bacterial die-off. Research in the field shows that implemented biosand filters reduce fewer bacteria than ones in a controlled environment. In research conducted in 55 households of Bonao, Dominican Republic, the average E. coli reduction was found to be about 93 percent.

Viruses

Lab tests have shown that while the reduction of E. coli from these filters is quite significant, the attenuation in viruses is significantly less due to their small size. In a study using bacteriophages the removal ranged between 85% and 95% after 45 days of usage. A recent study has suggested that virus removal increases significantly over time, reaching 99.99% after a period of approximately 150 days.[2]

Protozoa

In one lab test the biosand filter also got greater than a 99.9% removal of protozoa. In tests for one type of protozoa, *Giardia lamblia* had a 100% removal for 29 days of usage. Another protozoa, *Cryptosporidium oocysts*, showed to have a slightly lower reduction (99.98%) possibly due to their smaller size. This removal showed to be comparable to that of the slow sand filter.

Health benefits

Studies in the Dominican Republic and Cambodia conducted by the University of North Carolina and the University of Nevada shows that BSF use reduced occurrence of diarrheal diseases in all age groups by 47%.

Field use

In a study conducted by CAWST in Haiti 95% of 187 households reported that they believed their water had improved since using biosand filters to clean household water. 80% of users stated that their families' health had improved since implementation. Health perceptions of the biosand filter use has shown to be more positive in long term users.

Types of biosand filters

Concrete

Concrete filters are the most widespread type of biosand filter, consisting of a durable outer core structure of concrete. Concrete is generally preferable to other materials because of the low cost, wide availability, and possibility to be completely constructed on-site. Concrete filter production further allows for entrepreneurship amongst the local community. The plans for the concrete filter are distributed openly by CAWST. Several versions have been developed. The CAWST Version 9 biosand filter is constructed with a higher maximum loading rate and although the filtered water passes EPA water quality standards it is not optimal. Recent research establishes that contact time between the water and the granular material is the leading determinant in purifying water. The CAWST Version 10 biosand filter takes this into account as the volume of the water reservoir is equal to the pore space volume of the sand layer, with a maximum loading rate decreased by 33% to ensure stagnant water in constant contact with granular material.

Plastic

Plastic filters are constructed of plastic barrels, usually formed offsite. Hydraid biosand filters are constructed of medical grade plastic with UV resistance.

References

[1] Elliott, M., Stauber, C., Koksal, F., DiGiano, F., and M. Sobsey (2008). Reductions of E. coli, echovirus type 12 and bacteriophages in an intermittently operated 2 household-scale slow sand filter.Water Research, Volume 42, Issues 10-11

[2] Bradley, I., Straub, A., Maraccini, P., Markazi, Nguyen, T., (2011). Iron Oxide Amended Biosand Filters for Virus Removal. Water Research

External links

- Biosand Filter Knowledge Base (http://www.biosandfilters.info) containing latest technical and implementation information, research and project information
- CAWST Biosand Filter (http://cawst.org/bsf) containing training and education resources
- Manz Water Info (http://manzwaterinfo.ca/) containing a number of detailed resources relating to construction and operation
- BioSand filter (http://waterfilterx.com/biosand-filter/)

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