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Household Biosand Water Filter

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Abstract— The BSF technology has been patented in Canada, the United States and several other countries. The development of the BSF technology for humanitarian purposes was greatly accelerated by opportunities for its commercialization. The BSF technology is not limited to household concrete filters. A wide variety of plastic, stainless steel, and concrete BSF's ranging in capacity from 20 to 1,000,000 liters per hour are available under license from the Canadian company, Pure Filtered Water Ltd.,Calgary, Alberta, Canada. Only the household concrete BSF is available without royalty of any kind to everyone worldwide, without limitation, provided they are appropriately trained and faithfully represent the BSF technology. A number of household water treatment and safe storage technologies, such as chlorine disinfection, solar disinfection, and ceramic filtration, have been documented for their ability to reduce diarrheal disease and improve microbial water quality. The biosand filter (BSF) is a promising household water treatment technology in use by > 500,000 people globally. [1]

Keywords— Biosand filter (BSF), diarrheal disease, HWTS (household water treatment system), Schmutzdecke, Moringa

I. INTRODUCTION

Globally, 1.1 billion people are without access to improved water supply or nearly one fifth of the world population. (WHO / UNICEF, 2000, p. 7) Figure 1 illustrates the global differences in improved drinking water use. Within one region, urban coverage is mostly higher than rural coverage, with the greatest differences between urban and rural water access in Africa and Oceania. In 1990, 77 % of the world population used improved drinking water sources. Considerable progress was made between 1990 and 2002, with about 1.1 billion people gaining access to improved water sources. Global coverage in 2002 reached 83 %, putting the world on track to achieve the MDG target. The region that made the greatest progress was South Asia, which increased coverage from 71 – 84 % between 1990 and 2002. This jump was fuelled primarily by increased use of improved water sources in India, with a population of over 1 billion people. Progress in sub-Saharan Africa was also impressive: coverage increased from 49 – 58 % between 1990 and 2002.But this falls far short of the progress needed to achieve the MDG target to reduce by half the proportion of people without sustainable access to safe drinking water by 2015. Obstacles to accelerating the rate of progress in sub-Saharan Africa include conflict and political instability, high rates of population growth and low priority given to water and sanitation. What's more, breakdown rates of water supply systems in rural Africa can be very high. Despite these obstacles, decentralising responsibility, ownership and providing a choice of service levels to communities, based on their ability and willingness to pay, are among the approaches shown to be effective in speeding up progress. (WHO / UNICEF, 2004, p. 10) [2]

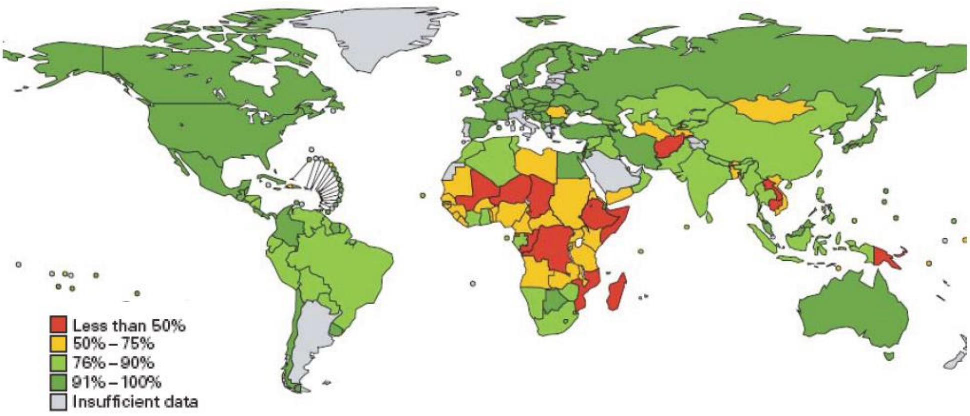

Figure 1. Percentage of population using improved drinking water sources in 2004. (WHO/UNICEF, 2006, p. 8)

II. THE OBJECTIVES OF HOUSEHOLD WATER TREATMENT

Currently, 1.1 billion people lack access to improved water sources (e.g. a household connection or a public standpipe). However, many more are supplied with water unsafe for consumption. (WHO/UNICEF, 2000, p. 7) The Millennium Development Goal 7, Target 10, calls for reducing by half the proportion of people without sustainable access to safe drinking water by 2015. Reaching this target implies tackling both the quantity and quality dimensions to drinking water provision. However, studies suggest that depending on local conditions, a significant proportion of water from these sources may be contaminated. In the light of these findings, great efforts are required not only to extend services to the unserved but also to ensure these services are indeed supplying safe water. (WHO, 2007, p. 13) A recently published study estimated that improvements in drinking water quality through household water treatment lead to a reduction of diarrhoea episodes by 39%. (Fewtrell et al., 2005 in WHO/UNICEF, 2005, p. 13) Household-level interventions can make an immediate contribution to the safety component of this target and would significantly contribute to meeting the MDGs in situations where access to water supplies is secure but household water quality is not ensured. (WHO, 2007, p. 13) The availability of sufficient water is key to a consistent practice of hygiene behaviour. Therefore, the objective of HWTS is not to replace the installation of water supply infrastructure but to complement the effort in providing safe drinking water to the consumers and, therewith, contribute to reducing global diarrhoea. Focus of this module is on the treatment of water at household level. It addresses the systems and technologies used to improve the microbiological water quality, their operation, as well as their advantages and limitations. The question of safe storage of drinking water is also discussed. The aspects of water resource management and water supply are not discussed in detail in this Module. The availability of sufficient water is key to a consistent practice of hygiene behaviour. A HWTS must:

- Reduce the risk of disease transmission through drinking water by supplying safe water achieved through
    - protection of the source
    - treatment at the source
    - safe delivery
    - treatment at household level
    - safe storage to prevent recontamination
- Be affordable to all
- Be easy to operate and maintain
- Be culturally acceptable [2]

III. BIOSAND FILTRATION

The BSF is very similar to the slow sand filters but its use is on a much smaller house hold scale than slow sand filtration. Moreover, biosand filtration is still a relatively new technology that is being applied in the developing world prior to the implementation of the BSF, studies should be completed on the social, economic, and political factors of the developing country of interest. Only then could the BSF be a potentially sustainable and appropriate technology. The Biosand Filter (BSF) is a water filtering technology that was modified from the traditional large-scale community slow sand filter to a small-scale filter for household use. The BSF was developed in 1988 by Dr. David Manz of the University Of Calgary, Canada, in response to various issues that were brought to attention from previous water treatment projects. The issues the BSF had to face were higher flow rates than the traditional slow sand filter, effective pathogen removal, improve the taste and appearance of the water, allow for intermittent flow, and still provide an appropriate technology for the developing world.

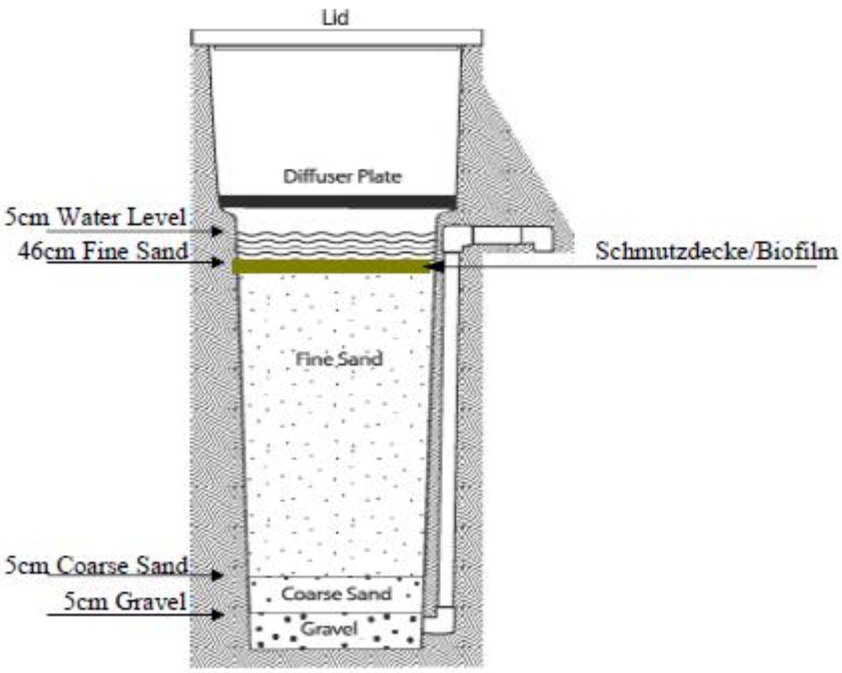

Figure 2. Illustration of a BSF unit

The function of the BSF begins with the raw water entering into the top of the filter where a diffuser plate is situated above the sand bed and dissipates the water at a regulated flow. The regulated flow is an important factor so as to prevent the disturbance of the biofilm. The water then travels slowly through the sand bed, followed by several layers of gravel, and then collects in a pipe located at the base of the filter. During this time, the water is driven through PVC piping and out of the filter for the user to collect the filtered water. The BSF is similar to the slow sand filter in that the majority of the filtration and turbidity removal occurs at the top layer of the sand bed due to the decreasing pore size caused by the deposition of particles. The BSF removes the pathogens through the same process as in slow sand filtration: as the suspended solids pass through the sand in the filter, they will collide and adsorb onto the sand particles. The processes by which the suspended solids collide and adsorb are straining and adsorption. The bacteria and suspended solids begin to increase in the greatest density at the top layer of the sand, leading to a gradual formation of the biofilm. The biofilm layer is also known as the Schmutzdecke (= dirt blanket) and these two terms will be used interchangeably throughout this report. The Schmutzdecke, which consists of algae, bacteria, and zooplankton, requires the water level to be 5cm above the biofilm in order to survive. As well, the biofilm needs both an aquatic environment and a constant influx of oxygen. Therefore, if the water level above the biofilm rises above 5cm the oxygen should not diffuse to the Schmutzdecke layer, which would lead to the suffocation of the biofilm. However, if the water falls below 5cm then the inflow of the water through the diffuser will disturb the biofilm. The 5cm water level is quite important to the efficiency of the BSF for the main reasons of preventing the sand from drying on the top layer, and to allow for sufficient oxygen to be maintained for the biolayer by having an outflow pipe in which the pipe stands 5cm above the top of the sand.

The biofilm involves a set of biological mechanisms in which it is not easy to pinpoint a specific mechanism that attributes to the removal, as the system operates in multiple biological and physical mechanisms.

The biological mechanisms include:

1. Predation: where micro-organisms within the Schmutzdecke consume bacteria and other pathogens found in the water (i.e. bacteria grazing by protozoa)
2. Scavenging: detritus are scavenged by organisms such as, aquatic worms that are found in the lower layers of the sand beds.
3. Natural death/inactivation: most organisms will die in a relatively hostile environment due to increased competition. For example, it was found that E Coli numbers decrease as soon as they are introduced into the filter supernatant water.
4. Metabolic breakdown: is a step that accounts for partial reduction of the organic carbon.

The physical mechanisms include:

1. Straining: particle capture mechanism where particles are too large to pass through the media grains.
2. Adsorption: even though a physical process, it still accounts for organic removals that were traditionally attributed to purely biological effects.

It should be noted that there are more biological mechanisms involved in sand filtration; however the five steps mentioned above are the most crucial influences to pathogen removal.

Aforementioned, slow sand filtration is very similar to the mechanics of the BSF. However, there are three definite limitations of slow-sand filter with regards to household level water treatment:

1) it demands continuous flow in order to provide constant influx of oxygen to the biofilm,
2) it is usually built on the scale for community use which requires a centralized water location and is too large for household applications, and
3) requires low level maintenance with regards to the cleaning of the Schmutzdecke layer.

Some of the main benefits of the BSF include:

1) Allows for intermittent flow and can be used only during the times when treatment is required without any decrease in performance.
2) Pre-treatment methods or other treatment process can be used before or after the BSF.
3) BSF has a faster flow rate of 0.6 m/h (30L/hr), whereas the traditional slow sand filtration rates are 0.1m/hr.
4) There is no surface scraping, media disposal or replacement, and very little wastewater.

The means of cleaning the Schmutzdecke is through a method called filter harrowing.

The sand within the filter does not need replacement and filter harrowing does not produce a lot of sludge, therefore waste levels are kept at a minimal.

The main components that comprise of the BSF are a rectangular, concrete box, a metal or plastic diffuser plate, PVC piping, and specifically graded layers of sand.

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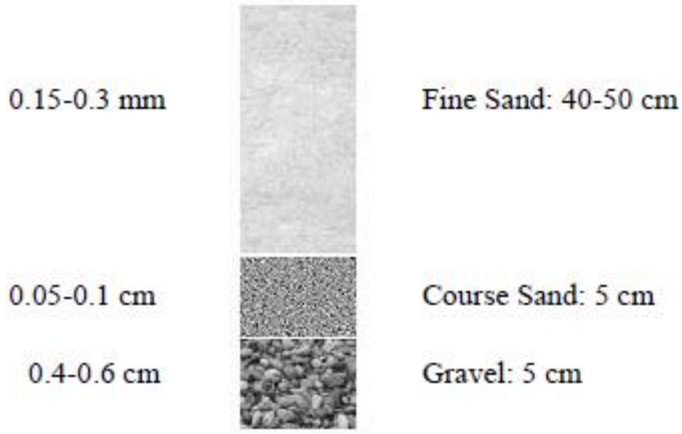

Figure 3. BSF media size (Basu, Cleary, 2003)

Filtration performance in slow sand filters is dependent on the physical characteristics of the filter sand, which include effective size. The effective size, also referred to as the media size, will only allow 10 percent (by weight) of a given water sample to be filtered through slow sand filtration. It should be taken into account that the media size in the BSF will be within the range of the slow sand filter but will not be exactly comparable to traditional slow filters. Most slow sand facilities report to have an effective size that ranges from 0.2 to 0.3mm. Since the flow rate of the BSF is much faster than the traditional slow sand filters and other filters, like candle filters (0.3 L/hr), I would not recommend that the media size of the sand in the BSF increase more than the current maximum size of 0.3mm. Increased hydraulic loading and increased media size would lead to increased particle breakthrough.

Taking into account that the BSF is versatile, and that biological treatment of the raw water is very successful, there are two major drawbacks of the current BSF technology. These drawbacks include:

1. The BSF's inability to handle high turbidity during monsoon seasons, where the high amount of rain and runoff greatly increase the turbidity. The high turbidity leads to increased particle deposition and decreased pore size. As a result, frequent clogging of mainly the top layer of the sand occurs, reducing the flow rate of the BSF greatly.
2. The cost of the BSF is also relatively high in most developing countries, depending on the availability of the materials.

Through the review of these drawbacks, this paper will derive certain alternatives that can lead to further research within the laboratory and possibly apply to overseas BSF projects. Some of the alternatives that will be reviewed are pre-treatment methods, media size of the sand, and a study done on the cost of the BSF. As well, this paper will address some of the important non-technical aspects of BSF implementation in developing countries, such as, education and community involvement.

The two main concerns related to the implementation of the BSF are its incapacity to manage high turbidities during monsoon seasons and its high initial cost.

In order to address the BSF's problems with respect to high turbidities clogging the BSF, three pre-treatment alternatives are suggested.

- The first alternative involves the application of roughing filters, where one or two rapid filters in series would be followed by the BSF. This method resolves the high turbidity problems; however, it is not recommended due to its high increase to the initial costs of the BSF.
- The second method of pre-treatment is using powered Moringa tree seeds as a coagulant. Results from past studies showed that the Moringa solution can lower the turbidity levels to 5 NTU with doses of 3-24 ml/L. In order to simplify the operation of the BSF, it is recommended that the Moringa seed coagulant only be applied during monsoon season. Whereby, only one dose of coagulant would be applied during the times the water was very turbid. Due to the low cost and efficiency of the powered Moringa coagulant, it is highly

recommended that it should be used as a pre-treatment method in regions where Moringa trees are readily available. It should be noted that past studies have not shown that Moringa seeds have any adverse affects on the biofilm, however, this concern should be researched further.

- The last pre-treatment alternative reviewed is the use of a sari cloth. This method is the cheapest, least labour intensive, and requires little training because many local people use this method already in areas such as India. The pore size of the sari filter can be as small as 20μm, which captures many of the SS and bacteria. It is assumed that many other materials would have similar results to the sari cloth, however, it is recommended that further research should be performed regarding this matter. Additionally, an investigation into the possibility of replacing the BSF diffuser with the sari cloth is recommended. The sari cloth filtration is one of the most practical pre-treatment methods because of its simplicity and high particle removal capabilities. [3]

IV. CONCLUSION

Prior to the implementation of the BSF, studies should be completed on the social, economic, and political factors of the developing country of interest. Along with studies on the socio-economic situation, education is crucial to the success of the BSF being properly operated by the local people. Only then could the BSF be a potentially sustainable and appropriate technology. It is essential for the implementation of large scale BSF project (i.e. over 100 BSF being implemented in a developing country) to form a highly interdisciplinary team in order to tackle the social, economical, health, and educational facets that the project will face.

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