ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF CIVIL ENGINEERING & ARCHITECTURE

Department Of Construction Management Technology Teacher Education
A Project in partial fulfillment of the requirement for the Degree of Master of Science in Construction Management Technology Teacher Education

Title: - Investigating the Effectiveness & Performance of Biosand filter for Community Water Treatment

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Advisor: Mr. Behailu Abebe

June 2015
ADAMA, ETHIOPIA

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Declaration

We hereby declare that this project report entitled “Investigating the Effectiveness & Performance of Biosand filter for Community Water Treatment” is the result of our own research except as cited in the references. This project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Acknowledgement

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ABSTRACT

Water is essential to sustain life, and when supplied as drinking water to consumers, a satisfactory quality must be maintained so that, provision of water, sanitation and good hygiene services are vital for the protection and development of human resources. Though BSF is much better than surface water in terms of biological quality, lack of source protection and inefficient treatment, waste management and sewerage system problem, poorly designed pit latrines and poor hygienic practice at the households affect the quality of the water. Therefore, assessment of bio-sand filter (BSF) and microbiological quality of drinking water from sources to house hold in selected communities of rural areas.

The bio sand filter is a modified form of the traditional slow sand filter in such a way that the filters can be built on a smaller scale and can be operated intermittently. These modifications make the bio sand filter suitable for household or small group use.

The bio sand filter can be produced locally anywhere by using materials that is readily available. It should be used as part of a multi-barrier approach which is the best way to reduce the health risk of drinking unsafe water.

This paper reviews the practical application of BSF. The media properties, water requirements, filter cycle time and water temperature is identified as the most important parameters.

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LIST OF ABBREVIATIONS

ACI	Aqua Clara international
BSF	Biosand Filter
CAWST	Center for Affordable Water and Sanitation Technology
CDC	Center for disease control
CFU	Colony- forming unit
CHP	Community health promoters
DALYs	Disability Adjusted Life Years
E. coli	Escherichia coli
EDWQ	Ethiopian Drinking Water Quality
EWB	Engineers without boarders
HWT	Household water treatment
HWTS	Household water treatment and safe storage
LPD BSF	Local plastic design Biosand Filter
MF	Membrane Filtration
NGO	Non-governmental organization
NTU	Nephelometric Turbidity Units
^{O}C	Degree centigrade
P/A	Presence Absence
POU	Point of Use
QTY	Quantity
SODIS	Solar disinfection

SSF	Slow Sand Filtration
TSS	Total Suspended solids
TU	Turbidity Units
UC	Uniformity coefficient
USD	United states dollar
UV	Ultra violet
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background

Access to clean water, free of pathogens and other contaminants, is essential for human life and vital for the development of healthy communities. Nonetheless, there are 1.1 billion people worldwide without access to safe drinking water, and there are 1.6 million deaths every year attributable to the lack of access to safe drinking water and basic sanitation; 90% of these deaths are among children under the age of five (WHO 2005). The majority of these cases are in rural areas of developing countries, where centralized water distribution systems do not exist or are unable to provide clean water to the community. In order to solve this problem the BSF technology is to purify water at the point of use are among the available alternative. Biosand filters are modified household-scale slow sand filters that provide microbiologically safe drinking water by removing biological contaminants that cause amoebic and bacillary dysentery, typhoid, and cholera.

Unlike chemical disinfection or solar disinfection, these filter can not only improve the microbiological quality of the water, it can also improve the appearance and taste of the drinking water.

It is unique compared to many of the other currently available treatment technologies because laboratory evidence indicates that performance improves with use due to development of a biologically active surface later (Buzunis, 1995; Stauber et al., 2006). Other technologies have been known to break over extended periods of use or to experience decreased effectiveness and decreased levels of usage after extended periods of time (Arnold &Colford, 2007).

The BSF is modified forms of conventional slow sand filter (SSF) in that there is typically no pretreatment or backwashing and operation is simple, with gravity-driven rather than mechanical pressure filtration. As a result, this technology is effective and sustainable in the long term. Their ease of construction and simplicity of operation make them more sustainable than most competing systems.

1.2 Statement of the problem

Problem related to project

When the materials are prepared for the effectiveness and performance of biosand filter the problem faced are:-

- When sand is sieved and washed it takes a long time and exhausting,
- It is difficult to obtain cleaned coarse aggregate and gravel easily,
- It is not available to get the source of the project sample water near urban areas,
- Lack accessibility of laboratory to test the water sample in surrounding areas.

1.3 Objective of the Project

1.3.1 General Objectives

To investigate the long-term sustainability of Biosand Filter use in rural communities.

1.3.2 Specific Objectives

- To evaluate the long term performance of the BSF.
- To determine the ability of the Biosand filter to reduce concentrations of total Coli forms and E. coli in water.
- To determine the performance of the Biosand filter to reduce household diarrheal disease.
- To develop effective plastic BSF that would serve for water treatment.

1.4 Significance of the Project

Water is treated at point of use; there is less risk of contamination during transport. Easy to use pour water in the top and it pushes out water that has passed through the sand layers. There's almost no energy required, no moving part and nothing for the user to do but make sure a clean container is available for the improved water. It is easy to maintain and operate, so people are able to use it every time when they need water. After filtering, the water tastes better, has less sedimentation, and cools as it passes through the sand. It reduces incidents of diarrhea, removal of protozoa and the majority of bacteria, acceptability to users because of high flow rate, ease-of-use, and visual improvement in the water. It is produced from locally available materials; its capital cost is low relative to other filter and one-time installation with low maintenance requirements; and it stays a long life.

1.5 Scope of the Project

The project addresses the general objective and evaluates the effectiveness and performance of the bio sand filter for community water treatment.

1.6 Limitations of the Project

If the Source water is high turbidity (> 500 NTU) will cause filter to clog more frequently. It cannot remove all pesticides or fertilizers (organic chemicals), cannot remove salt, hardness and (dissolved compounds). It does not filter out every pathogen, low inactivation of viruses, absence of post-filtration residual protection so that if water is filtered into an open or unclean bucket there is potential for contamination.

CHAPTER 2

REVIEWS OF RELATED LITERATURES

2.1 Introduction

This chapter covers different types of BSF, Effectiveness and Performance of Biosand Filters, focuses on Biosand Filters and its implementation and various point-of-use (POU) water treatment methods. The development of this particular technology is discussed to reveal how it evolved from community-scale slow sand filtration to a household intermittent filter made of concrete, and then to a new design made of light-weight plastic.

A biosand filter is a simple type of water purification system that uses sand, coarse aggregate and gravel to purify water contaminated with biologics and some chemicals. Its structure is generally made of concrete or plastic and is filled with layers of gravel and sand that encourage the growth of good microbes that are naturally present in water, just like in the ground in nature. These good microbes develop into what's called a "biolayer" or a "biofilm," which destroys pathogenic (i.e., disease-causing) microbes to create clean drinking water. The sand also causes pathogenic microbes to become trapped, adsorbed (i.e., stuck to the sand particles) or die from lack of food or oxygen. (EWB San Dieg Professional Chapter wedsite).

2.2 Types of BSF

2.2.1 Slow sand filter

Conventional slow sand filtration (Figure 2.2) has been used for several centuries throughout Europe and in developing countries for the effective treatment of drinking water. It is different from rapid sand filtration mainly because it contains biological activity. For this reason it is also referred to as biological sand (Biosand) filtration. The technology is a combination of four biological and mechanical processes (Figure 2.1) to remove pathogens and other contaminants (CAWST 2006)

1. Mechanical Trapping: The primary process for removal of pathogens, mechanical trapping is the physical filtration of particles and organic material as they pass through the filter. Sand grain sizes are usually 0.1 – 1.0 mm and the pore spaces are usually less than this. Large materials such as grass, leaves, silt, or clay particles, along with large pathogens like parasites, helminthes

and worms are trapped in the pore spaces. Smaller pathogens such as bacteria and viruses are trapped by the same process when they are attached to the larger particles. The filter removes 60-90% of all pathogens (over 99.9% of large pathogens) during this process.

2. Predation: Organic material is trapped at the surface of the fine sand and forms a complex biological layer, much like a pond or wetland ecosystem, where microorganisms grow and thrive. Referred to as the schmutzdecke– a German word for “dirty layer” – the composition of the top 1-3 cm varies depending on the source water.

However, it will typically consist of a gelatinous biofilm of bacteria, fungi, protozoa, rotifer, and a range of aquatic insect larvae. These microorganisms gain nitrogen and carbon by consuming nutrients from the organics and other pathogens in the source water. Larger microorganisms consume smaller ones. Stronger ones consume weaker ones. Living ones consume dying ones. The series of predation is an active food chain within the schmutzdecke. Oxygen is necessary for these aerobic organisms to survive.

This is provided by dissolved oxygen in the source water. (Intermittently operated sand filters differ from conventional designs in that additional oxygen is diffused through the static layer of water above the sand. If the water is too deep (>8cm) the oxygen cannot diffuse enough to get to the organisms.)

3. Adsorption: Pathogens and particles, attracted due to electrical and cohesive forces, attach themselves to one another and are thus trapped in pore spaces. Bacteria and viruses can also attach directly to the sand particles that compose the filter media. Once attached they are metabolized by the cells or inactivated by antiviral chemicals produced by organisms in the filter. As the biofilm starts to grow it tends to attract an increasing amount of particles to it. This takes place in the biological zone (or biolayer) of the filter, roughly 5-10 cm from the surface. After this depth biological activity curtails due to lack of nutrients and oxygen.

4. Natural Death: Different from predation, this refers to the “natural” die off rate or life expectancy of the microorganisms. If they are trapped long enough within the filter the pathogens will die from food scarcity or less than optimal temperatures before exiting the filter. This can also occur if the pause period is long enough – some organisms have life-spans of only a few hours – or if aerobic organisms are trapped deep within the filter where oxygen is not available.

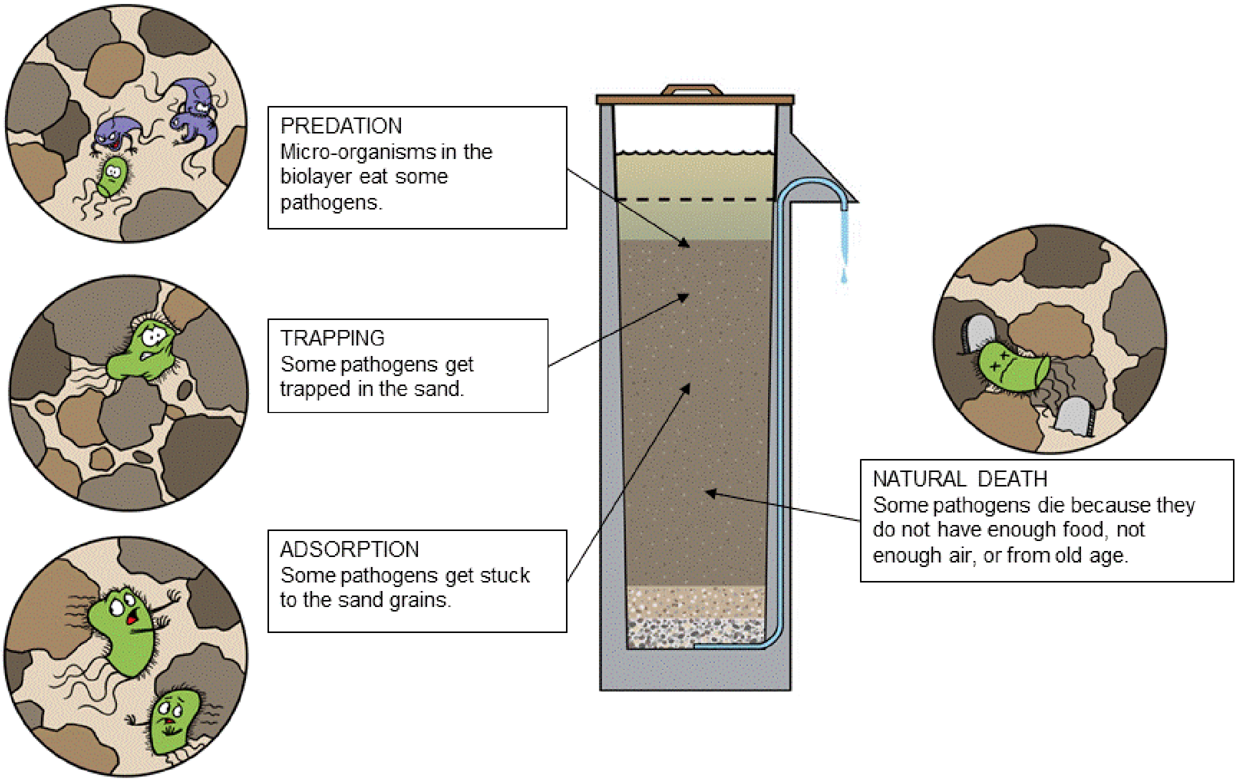

Figure 2.1: Biological and mechanical processes

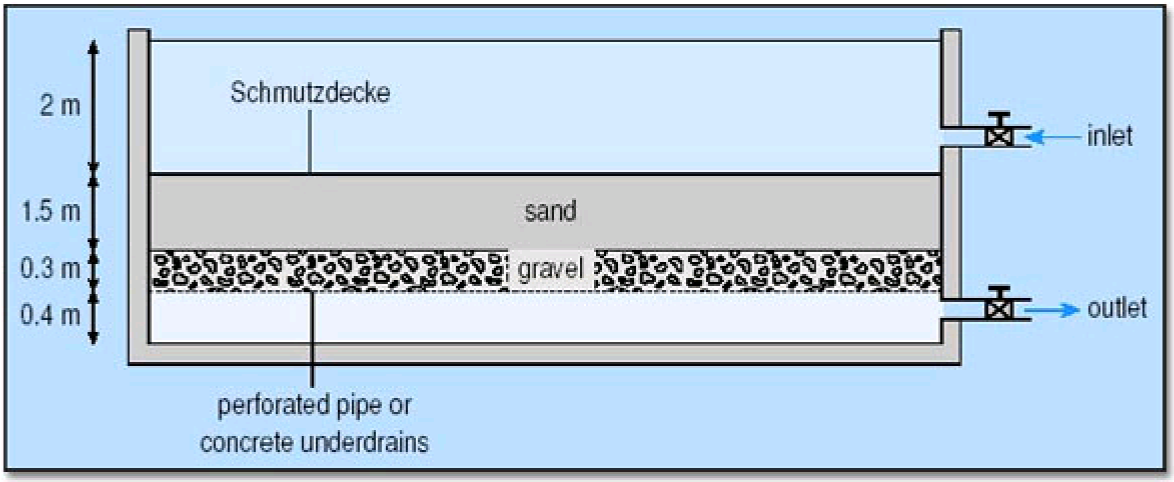

Figure 2.2: Conventional slow sand filters operate continuously to provide enough dissolved oxygen from the source water to the microorganisms in the Schmutzdecke and biological zone (Adapted from www.openlearn.com).

2.2.2 Concrete BSFs

Concrete filters are the most widespread type of biosand filter. Concrete is generally preferable to other materials because of the low cost, wide availability and the ability to be constructed on-site. 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. (CAWST Biosand Filter Manual 2010)

Manz's design, illustrated in Figure 2.3, utilizes a container made of concrete and stands approximately 95 cm in height and 36 cm in width. Weighing 150 kg empty, the filter can surpass 225 kg when filled with filter media and water. Due to their high flow rates of 30-40 L/hr the filters can easily provide enough clean drinking water for an entire family each day. The cost varies depending on the country – ranging from $10 to $40 USD – and averages around $25 USD per filter (Duke et al 2006). The Biosand Filter (henceforth referred to as BSF) is particularly suitable for use in low-income countries where populations still rely on untreated, contaminated surface water.

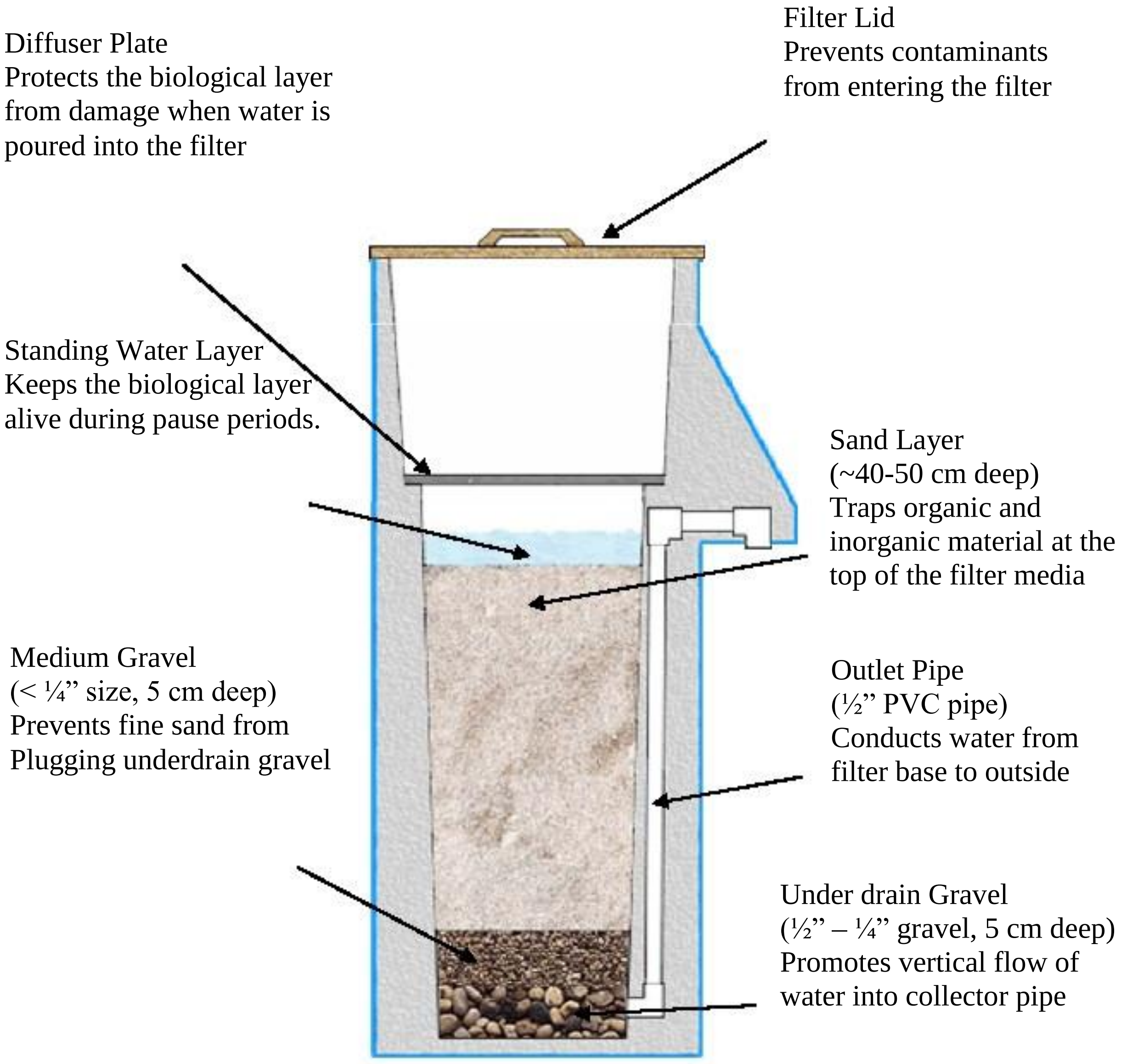

Figure 2.3: The concrete Biosand Filter is a technology modified from the conventional slow sand filter (Adapted from CAWST 2006).

2.2.3 Plastic BSFs

Plastic filters are constructed from plastic barrels, usually formed offsite. Hydraid biosand filters are constructed from medical grade plastic with UV resistance. (Hydraid Biosand Technology) TivaWater is the newest version of the biosand filter and has several important improvements. (tivawater.com)

2.3 Effectiveness and Performance of Biosand Filter

Kubare and Haarhoff (2010) identify the BSF as an important POU water treatment system because it is self-sustaining, decentralized and affordable. The researchers give an excellent description of how the BSF works: The filter consists of a bed of fine sand supported by a layer of gravel enclosed in a box with appurtenances to deliver and collect the water. When water is poured onto the top of the filter, particulate matter is trapped at the surface, where a biological layer (also called the schmutzdecke) develops after a period of filter ripening. The biological layer is responsible for trapping and partly eliminating sediments, pathogens and other dissolved impurities from the water. Within the gravel support layer below the filter media are under-drains to remove the filtered water. (Kubare & Haarhoff, 2010, p. 1)

The BSF has advantages of robust and durable design, simple user operation and maintenance with no recurring purchases, high flow rate (30–60 liters per hour) sufficient for domestic and drinking needs, ability to treat highly turbid waters, and local fabrication resulting in affordability (US $15–25 ⁄ unit) (Tiwari et al., 2009, p. 1374).

Stauber, Printy, McCarty, Liang, and Sobsey (2011) conducted a randomized control study examining biosand filter performance with 90 filter households and 99 control households not receiving filters. The researchers surveyed filters using plastic containers, utilizing the same slow sand filtration process as concrete framed BSFs. Both groups received hygiene education over an 8-month period. The filter group indicated a 59% reduction in self-reported diarrhea and water tests demonstrated improved quality after filtration. Significantly, this study showed a relationship between diarrhea incidence and filter use, but no relationship between turbidity and diarrhea reportages. This indicates a validity of the self-reporting diarrhea in these types of studies. If self-report of diarrhea was inaccurate, we would expect to see a higher correlation between the turbidity of the water and diarrhea, because it would be instinctive to associate the two. Clearly, it is a limitation of these field studies to rely on self-report of diarrhea, but it is hard to imagine a more objective measure of diarrhea that is practical. This was a rigorous study with a large sample and a control group. This study indicated that the plastic BSF has similar success rate of effectiveness as concrete framed filters. Plastic filters are lighter and cheaper – participants paid US$10 for their filters. The disadvantage is that it may be subject to breakage greater than the concrete filters, and due to its greater portability, movement of the filter can reduce effectiveness.

CAWST's construction manual (CAWST, 2011) summarizes the overall success of the BSFs in prior published research. The following table shows the percentage of pathogens and turbidity removed by BSFs:

Table 2.1 - CAWST's summary of BSF effectiveness

	Bacteria	Viruses	Protozoa	Helminthes	Turbidity
Lab	Up to 98.5%	70 – 99%	>99.9%	Up to 100%	95% <8NTU
Field	87.9-98.5%	NA	NA	Up to 100%	85%

CAWST cites several studies that estimate the health impact of BSFs, usually information acquired via self-report of diarrhea. These studies indicate a 30-61% reduction in diarrhea in all ages (CAWST, 2011).

CAWST concludes that the advantages of the BSF are, "locally available material, high pathogen removal, high flow rate, designed for household use from locally available material" (2011, para. 18). The disadvantage is that it does not remove all pathogens.

The Center for Disease Control nicely summarizes the advantages and disadvantages of slow sand filtration:

Table2.2 CDC's summary of BSF

Advantages	Disadvantages
.Proven reduction of protozoa and most bacteria . High flow rate of up to 0.6 liters per minute . Simplicity of use and acceptability	.Not as effective against viruses . No chlorine residual protection - can lead to recontamination . Routine cleaning can harm the bio layer and

. Visual improvement of the water . Production of sufficient quantities of water for all household uses . Local production (if clean, appropriate sand is available) . One-time installation with low maintenance requirements Long life (estimated >10 years) with no recurrent expenses	decrease effectiveness . Difficult to transport due to weight - high initial cost

The CDC points out that “Slow sand filtration (SSF) is most appropriate where there is funding to subsidize the initial filter cost, available education for use and maintenance, locally available sand, and a transportation network able to move the filter” (CDC, 2011 para. 5). To summarize, BSFs themselves have been demonstrated to be effective POU technology at reducing pathogens and diarrhea in a manner appropriate to many conditions in the developing world.

2.3.1 Implementation and Follow-up to BSFs`

Over a 4-year period from 2008 – 2011, Tear fund funded a project resulting in the production and sale of BSFs in Afghanistan (Burt, 2011). The authors of Biosandfilter.org advocate a similar approach of making BSFs more sustainable by creating a commercially viable local means of production. They specifically cite examples in Kenya where local residents made a business out of producing BSFs and continue to make more (Biosandfilter.org, 2012). Biosand filters are seen as particularly useful in areas where there is turbidity in the water because it produces a visible improvement in the water.

Aiken, Stauber, Ortiz, and Sobsey (2011) made some general statements summarizing other follow-up research on BSFs: Some evidence of BSF continued use has been documented, but few, if any, rigorous field studies have been conducted to assess sustained improvements in drinking water quality and user health. Among 107 households in Haiti in which the BSF had been implemented for more than 2 years, 105 households were found to still use the filter, with average Escherichia coli reduction of 98.5%. Among more than 300 households in Cambodia surveyed up to 8 years, 87.5% were found to still be using the BSF. (Aiken et al., 2011, p. 309)

They found in their own follow-up study of 328 households using BSFs in Cambodia, 90% of the BSFs were still in use indicating an 84-88% reduction in fecal indicator bacteria.

Many follow-up studies examining long-term use identify a need for improving the users' education about how to use the filters. In another follow-up study to evaluate the long-term sustainability of biosand filters Fewster, Mol, and Wiesssent-Brandsma (2004) conducted a study in Kenya. They were interested in the performance of biosand filters in real life conditions in rural Africa after the experts have left. The researchers evaluated filters 4 years after installation. These particular filters had been introduced by Medair, a Christian relief NGO based in Switzerland, in 1999. The filters were constructed by local technicians and sold to individual households. Customers received a brief training in maintenance when they received the filter. As of 2004, 2000 filters had been sold at the price of 12 Euros (Fewster et al., 2004). They used the Bushproof improved round mold. The researchers evaluated 51 filters and found 70% of them producing water of good quality. Fewster et al makes an interesting observation about the relationship between the amount of pathogens in the water and actual illness in the drinker:

Based on these results it is interesting to discuss the relation between levels of pathogen reduction and the risk of catching water-borne disease.

Developing an illness depends on many factors, such as the general health of a person and his level of immunity. In addition, exposure to a significant 'infectious dose' is often needed. If this increased quantity of water is more than his normal consumption, then it is unlikely that this person will fall ill. (Fewster et al. 2004, p. 2)

The researchers commented on education as a way to improve filters' overall functioning, "the original project did not use intensive teaching methods and it is likely that better information, teaching of cleaning methods, or improved or more frequent follow-up will lead to much better results" (Fewster et al., p. 4). The researchers suggested better results would occur if the biosand filters were cleaned only when the flow rate decreased to an unacceptable level, using a method that does not disturb the biofilm layer. The researchers also pointed out those two positive marketing mechanisms of the filters: reduced turbidity and cooled effluent water.

Duke et al. (2006) investigated 107 of an estimated 2000 Manz Biosand filters that had been distributed in the Artibonie Valley of Haiti. The researchers hired and trained local workers out of a hospital in Haiti to conduct the surveys. They used a structured interview and took water 5 or 4 samples from the original water source to the family's drinking water container. The researchers gave a 20L water container as a thank you for the participants' time. In general, a successful filtration rate was indicated that E. coli removal at an efficiency of 98.5% and reduced turbidity. They found most filters to be working successfully after an average of 2.5 years since installation. The researchers found information pertinent to the long-term use and maintenance of the filters; many of the users did not know how to perform the maintenance procedure to improve flow, 36% indicated that they had not been visited by the local NGO, Community Development, since installation. Researchers found recontamination; E. coli concentrations were 7 times higher in the receptacle container than in the spout. The researcher's final conclusion was, "Education about water-borne diseases and methods of safe water storage disinfecting the stored filtered water should accompany the installation of the filter." (Duke et al., 2006, p. 9)

Earwaker conducted a long-term study of BSFs distributed in Ethiopia. The researcher examined BSFs that had been distributed 5 years earlier by Samaritan's Purse, Canada through the Ethiopian Kale Heywet Church. He found an E. coli reduction rate of 87.9%. The usage rates varied from 44-100% among different villages. The low usage rates and poor performance was attributed to quality of maintenance, lacking needed education, and lacking outside support. The study also threw into question the sustainability of BSFs in this region; the researcher suggested increased commercialization. In Earwaker's discussion, he points out that the BSFs would be much more efficient if they were properly maintained; users should use the proper cleaning procedure when the flow rate decreases. Other recommendations he makes are proper cleaning of the spout and more economically sustainable support structures. The researcher points out that the BSFs met with initial success due to the education that accompanied the BSFs but there was poor follow-up and reinforcement of educational messages. He concludes that, "Reinforcement of educational messages and distribution of promotional material could therefore be an effective and simple method to improve filter maintenance procedures and general hygiene behaviour" (Earwaker, 2006, p. 45).

Vanderzwaag, Atwater, Bartlett, and Baker (2009) conducted a follow-up study in Nicaragua investigating the condition of 234 filters three and eight years after installation. The researchers found only 10% of the filters were still in use after 8 years. Of those still being used they averaged a reduction of 98% total coliforms (Vanderzwaag et al., 2009). The researchers suggested the low use rate was a result of a failure of implementation and specifically the cracking of the earlier concrete filters. The authors also suggested that user training and filter maintenance could improve filter performance. They observed, "much confusion among the filter users in Posoltega regarding filter maintenance, suggesting insufficient user training" (Vanderzwaag et al., 2009, para. 37). Vanderzwaag listed several failure mechanisms contributing to the BSFs disuse: cracks in the bodies, dislodged pipes, damage sustained when users moved the filters due to Hurricane Mitch, family dislocation, improper curing time in construction causing cracks, and improper unloading of the filter. There was no difference in performance between the filters that were three years old and eight years old. This indicates that this is a potentially sustainable, long-term technology. The researchers also suggested that there was a need for improved quality control of building and delivering the filters to reduce cracking of the concrete structures.

CAWST published a case study of implementation of Biosand filters in 2011. They reviewed a program conducted by Aqua Clara International (ACI), a non-profit NGO in USA and Kenya. They distributed more than 1800 biosand filters between 2007-2011. ACI developed a filter using the same intermittent slow sand process but in a plastic container body. ACI endeavored to make this biosand filter as locally driven and sustainable as possible. They created and supported a local business that constructs and sells biosand filters, safe water storage containers, and hand washing containers through a local school.

The businesses make money via the profits from selling each filter and received a financial incentive from ACI for monthly sales exceeding 5 filters. The business operators are responsible for training the user on how to use the filter, store water, and cleaning maintenance via the swirl and dump method. ACI also recruited local women, Community Health Promoters (CHP) to make household visits 30-60 days.

2.3.2 Intermittent Biosand Filters

Due to the need for a continuous supply of food and oxygen from the source water, it was previously considered impractical to operate a slow sand filter intermittently. The biological organisms would start to die even after a few hours of halting the continuous flow of water.

However, in 1995 Dr. David Manz from the University of Calgary redesigned the traditional sand filter to be able to operate with significant pause periods. His simple innovations downsized the filtration bed into a small vertical unit and extended the outlet pipe from the bottom under drain up to approximately 5 cm above the sand layer. The latter adaption allowed for adequate diffusion of oxygen through the supernatant to the biolayer during the resting periods. Suddenly, the community-sized technology of slow sand filtration was able to operate just as effectively as a smaller unit at the household level (biosandfilter.org 2004).

2.3.3 Operation

The BSF is especially noted by users for its high ease of operation. The technology is without any valves, moving parts or electrical requirements. The lid is removed and a bucket or head pan of contaminated water can be poured into the top reservoir of the filter as necessary. The water then enters the diffuser pan which causes the water to spread out into many smaller openings to ensure the initial force of water does not overly disturb the schmutzdecke. The water filters through the biolayer, sand and gravel media and exits through the outlet pipe as the pressure increases to match the inside of the filter reservoir. After all added water has been displaced through the filter, the head falls to the height of the horizontal outlet, approximately 5 cm above the sand. Equilibrium of pressures in the filter and outlet pipe forces the effluent to stop (biosandfilter.org 2004).

2.3.4 Flow Rate

The microorganisms in the BSF are more closely confined to the surface than that of a continuously operated slow sand filter and are limited by the diffusion of oxygen across the supernatant. Due to a shallow biological zone there is an overall shorter contact time between the source water and biofilm, which decreases removal rates and water quality. In order to provide comparable treatment, slower flow rates are needed when operating the BSF. The percentage removal of pathogens has been found to be inversely proportional to the flow rate, which is controlled by the size and cleanliness of the sand layer during the installation process. Although BSF literature states a maximum flow rate of 1.0 L/min, CAWST recently recommended 0.6 L/min as the ideal flow rate for optimizing treatment effectiveness with adequate supply (www.cawst.org). Pause periods have also proven effective when operating the filter as they allow time for predation to occur within the biological layer. As the pathogens and substrate are consumed the flow rate is restored and hydraulic conductivity increases exponentially. This further improves reduction of pathogens. However, if the pause period is too long the microorganisms will consume everything and die off – thus decreasing reduction rates when the filter is used again. The BSF is most effective and efficient when operated intermittently and consistently. The optimal pause period is 6-12 hours, with a minimum of 1 hour and a maximum of 24 hours (CAWST 2006).

2.3.5 Influent Water Quality

The water supplied to the BSF can come from a variety of sources including rain water, groundwater (shallow wells or bore holes) and surface water (rivers, lakes, springs, reservoirs). For optimal performance the turbidity in the source water should be below 100 NTU to avoid premature clogging of the filter. If higher than this the water should undergo a pre-filtration, sedimentation or coagulation process. It is generally recommended that the water come from the cleanest water source available. However, it should be consistently taken from the same source since the biolayer in the BSF will become adapted to conditions where a certain amount of food is available. If the influent water is changed to a more contaminated source the microorganisms will not be able to consume the increased amount of nutrients and pathogens. This type of spike event may result in a reduction in water quality for several days afterward until the biolayer adjusts to the new substrate levels (CAWST 2006).

2.3.6 Effluent Water Quality

It normally takes a period of two to three weeks for the biological zone to mature in a new filter.

During that time the removal efficiency and oxygen demand continue to increase until leveling out and reaching maximum rates. After maintenance of the filter the removal efficiency also declines somewhat but has a quicker rebound period as demonstrated in (Figure2.4). Many water quality analyses have been performed over the last fifteen years by various government, research, and health institutions as well as NGOs with regard to the removal efficiency of BSFs.

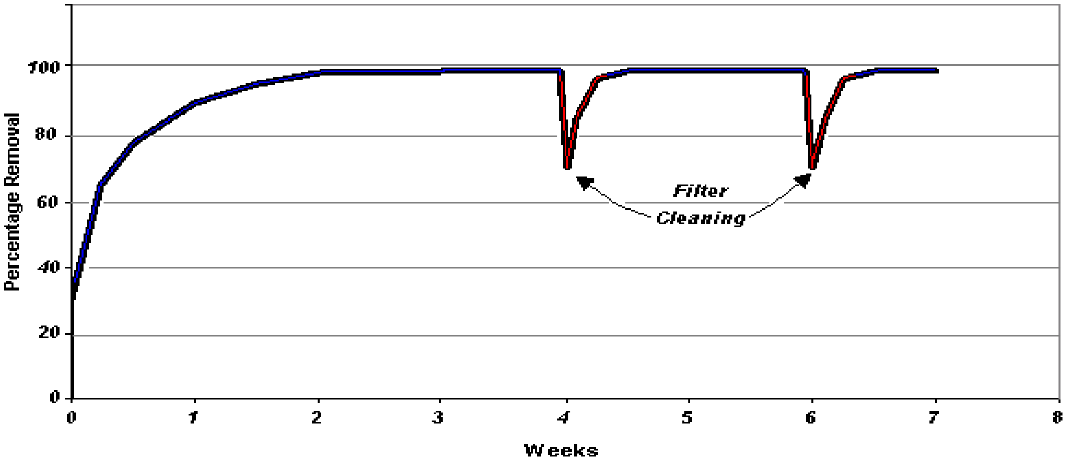

Figure 2.4: BSF removal efficiency graphed over time (Adapted from CAWST 2006)

2.3.7 Safe Storage

Although the filtered water is collected in a container of the user's choice, it is recommended for safety reasons that the collection be a closed system to prevent recontamination (Figure 2.5). The outlet pipe should flow directly into a clean durable container with a small opening – preferably raised and with a spigot on the bottom for easy access. An additional step of disinfection by chlorination or SODIS would further protect the stored water from recontamination.

Figure2.5: Examples of safe storage containers (CAWST Learning Aids2006)

2.3.8 Maintenance

Over time the pore spaces within the schmutzdecke will become clogged and the flow rate will reduce significantly. Although this will increase contact time and result in greater reduction of pathogens, the user will at some point desire a greater flow rate. Maintenance is simple and requires only a few minutes of time to perform what CAWST terms the “swirl-and dump” method. The reservoir is filled with additional water and the diffuser plate removed. The surface of the sand is agitated by hand or with a stick to suspend the captured material in the water (swirl). However, the surface layer should not be worked deeper than 5 cm. The dirty water is then bailed out with a small container (dump) and the process is repeated until the desired flow rate is reached. The biolayer tends to re-grow quickly and removal efficiency returns to the previous level (CASWT 2006). The spout and receiving container also need to be disinfected with chlorine solution or cleaned with soap and water on a regular basis to reduce the risk of recontamination.

2.3.9 Biosand Filtration Summary

Biosand Filters currently provide safe drinking water to over 200,000 households in over 70 countries around the globe (www.manzwaterinfo.ca).BSFs are not the only treatment option available to the developing world and must be evaluated based on a framework of criteria in the context of site-specific information. Once they are compared to other POU water treatment methods, the most appropriate technology can be selected. However, using only general parameters as in Table 2.3, intermittent BSFs appear to be a remarkably attractive household water treatment option. Other issues such as Local Demand for the Technology, Opportunity for Community Participation, Ease of Technology Transfer, and Economic Sustainability will vary with the participatory group (Lukas 2002).

Table 2.3: Design parameters including advantages and limitations for the concrete Biosand Filter (costs from CAWST 2006, parameters form Lukas 2002)

Parameter:	Advantages:	Limitations:	Comments:
Water Quality	LabRemoval:100% Protozoa 99.9%Viruses 99.5% Bacteria	Field Tests: 80-90% Viruses 90-99% Fecal coliformbacteria	60-99%bacterialremovalwhile biolayer is maturing; Overall less reduction than ceramic filters
Water	≤ 1.0 L/min,	Flow rate	CAWST currently

Quantity / Flow Rate	~30L/hr	Decreasesas biolayeris clogged	recommends flow rates of 0.6 L/min for the most effective water treatment
Robustness of Design	Very Durable: Concrete container w/ internal piping	Concrete Filter is heavy - Typically >300 lbs	Only component that may need to be replaced is the diffuser plate, depending on material
Technological Sustainability	All BSF materials local:Cement, wood, stones,sand,PVC piping	Start-up materials for production are costly (steel mold, screens, various tools)	Many implementing agencies provide training and materials to local BSF artisans to help them start a micro-enterprise
Obvious Importance to Users	Physical change in water appearance as filter reduces color and turbidity; Improved taste	Physical change varies based on source water & BSF performance	Education needed to explain how BSF removal mechanisms work, especially predation and function of non-visible biofilm
Maintenance	“Swirl-and-dump” method is free, easy and effective	Breaks up biolayer and removal rates decreasetemporarily	Performed when flow rate is too slow for the user, by the user
Costs	One time initial cost: $10.75 – $39.50 USD No maintenance costs	Many people cannot afford to pay the high initial cost upfront	Most implementing agencies offer the technology at a reduced/subsidized rate

2.4 Point Of Use water treatment methods

Biosand filtration is a point-of-use (POU) water treatment technology widely used in developing countries to improve drinking clean water.

Within the last five years, POU water treatment has gained momentum within the realm of public health as an effective way to reduce diarrheal disease in developing countries. Dr. Tom Clasen summarized during a lecture at Michigan Technological University that previous in-depth studies had found water treatment alone to have a lower impact than all other interventions (Esrey et al 1991). However, the studies had only included results from point-source treatment systems, not POU technologies managed at the household level. Recent studies exclusively analyzing POU treatment technologies in the field have shown reductions in diarrheal disease of up to 48% (Crump et al 2005; Brin 2003). Due to these findings POU water treatment is noted as a viable intervention for diarrheal reduction, and many organizations and institutions are implementing projects which focus specifically on these technologies or a combination of them with another intervention.

The following statistics, as reported by the authors, illustrate the depth of the problem in Sub-Saharan Africa in 2006: 31% of people of the population had access to clean water, 884 million deprived of improved sources of drinking water, 4 billion annual cases of diarrheal illness, 1.8 million lives lost each year due to diarrheal disease, 443 million school days lost each year from water-related illness, 117 million disability adjusted life years (DALYs) lost annually due to diarrhea and intestinal worm infections. Furthermore, Dye et al. identify more need: Several factors contribute to the lack of water sanitation in developing countries. First, large-scale water treatment is expensive and requires infrastructure capabilities that are often absent in low-resource settings. Second, household level interventions promoting water sanitation have obtained mixed results and are often cumbersome to implement and sustain. Third, it is difficult to motivate people to change their behaviors related to water access and consumption… Point-of-use water filtration has been demonstrated to be feasible in low-resource regions in Africa (De Ver Dye et al., 2011, p. 1515).

De Ver Dye et al. conducted a study distributing point of use (POU) water treatment systems in Western Kenya. They gathered data through qualitative interviews with 34 subjects. Two systems were used, one a Life Straw personal water filter, which is a large, thick straw worn around the neck allowing the user to suck water directly from a source. The other is a family Life Straw filter that is a decanter that disperses treated water. They also conducted a qualitative study measuring attitudes about diarrhea. They found that most people's existing understanding of the source of diarrhea, unclean water, food, and conditions, was in fact accurate. The researchers cited some problems with the study: small sample size and the sustainability of the filters. The filters in question much be purchased elsewhere. This study was conducted 2 months after the distribution of the water filters as part of a government program to distribute health-promoting materials called the Integrated Prevention Campaign, which included health education. The researchers concluded that water filtration was perhaps the best method of POU water treatment.

Clasen, Nadakatti, and Menon (2006) conducted a study in India using a household-based POU water treatment system and then assessed pathogens after use. They described research that POU water treatment systems have been "twice as effective in reducing endemic diarrhea as the conventional treatment at the source or point of distribution" (p. 1399). The researchers explained that POU water treatments are the most affordable and thus most sustainable. They conducted laboratory testing on the microbiological effectiveness of the Pureit water filter system made by Hindustan Lever Limited Company. The researchers were eager to test this technology in hopes of promoting a water treatment technology that was effective and affordable while promoting a commercially viable water filter. The study showed substantially reduced microbes from water. An advantage of this technology is that it utilizes both filtration and disinfection due to the use of chlorine. A disadvantage of this unit is the upfront cost and numerous parts requiring replacement and upkeep. The researchers suggest further research done in the field. They also suggest that users be well informed about the need to replace the filter cartridges inherent in this water filter technology. That is, there are potential problems with operator error when users do not conduct proper maintenance.

One would think that the ideal standard of research – a field study of water filters with a control group that has a placebo filter – would be impossible, but there is one such study. In 2010, Boisson, Kiyombo, Sthreshley, Tumba, et al. conducted such a study in the Democratic Republic of Congo. Their goal was to rule out reporting bias and the placebo effect documented in field studies of water filters. The researchers conducted a randomized, double-blinded, placebo-controlled field trial in 240 households, over the course of 12 months. All of the households received a Life straw Family household-based gravity filter. Half of the households received a placebo filter with the chlorine tablets removed. The placebo filters produced filtered water indistinguishable from the water issuing from a functioning filter, but did not kill pathogens via chlorine disinfection. The researches assessed diarrhea by visiting families every month asking primary caregivers of young children about diarrhea incidence. Diarrhea was defined as 3 or more loose stools in a period of 24 hours in the last 7 days. The researchers also asked about fever and cough in order to "further obscure the outcome of interest from the target population" (Boisson et al., 2010, para.16) to remove bias. The researchers tested influent and effluent filter water and found that the no placebo filters significantly reduced pathogens. However, they did not find a significant improvement in reported diarrhea in working filter households over placebo households. There was 15% reduction in diarrhea, but was not considered statistically significant given the parameters of the study. This shows that self-report of diarrhea is a problematic area of research.

Written consent to participate in the research was obtained from community leaders and the head of each participating household. Investigators explained that half of the study population would be receiving effective microbiological purifiers while the others would receive placebos and that householders should continue their existing water management practices since their device may not be protective against microbial contamination. At the conclusion of the follow-up period, all placebo filters were replaced by effective filters. Following the completion of the study, the results were communicated to all study participants. (Boisson et al., 2010, Para. 18)

Most field studies of filters do not use placebo filters for several reasons in addition to ethical concerns: pragmatic difficulties in creating nonworking filters, especially BSFs, logistical difficulties, resource and time limitations, and creating marketing and credibility problems with the local NGO or organization issuing filters.

There are many examples of POU water treatment technologies that are being promoted in lesser developed countries. These utilize three main categories of treatment methods (Sobsey2002):

1. **Physical treatment:** using boiling, heating, sedimentation, filtration and UV radiation exposure to neutralize and/or physically remove contaminants;
2. **Chemical treatment:** using coagulation, flocculation and precipitation, adsorption, ion exchange, or chemical disinfection to neutralize and/or remove contaminants; and

3. **Combined treatment:** using a combination of the above two processes.

Each specific technology has associated advantages and disadvantages and there appears to be no outstanding recommendation among them. The ideal one would provide the best performance at the lowest cost, which is not only sustainable but also acceptable to the user. However, these variables tend to change depending on geographic location and the cultural norms and values of the people. Examined below are the POU treatment alternatives that are currently available to improve drinking water supplies.

2.4.1 Boiling

Bringing water to rolling boil kills most pathogens in approximately one minute at sea level, and three minutes at altitudes above one mile (epa.gov/safe water/faq/emerg.html). This method has attained widespread throughout developing countries as an effective technology that is readily available (Figure 2.6). However, it is not regularly practiced simply because it is not an acceptable option to the users, i.e. – mostly women. They are the ones who fetch the firewood and water, and perform the cooking tasks in the home. For them, boiling water is time consuming and there is no visible change in the water to indicate an improvement. Plus, financial costs associated with boiling include increased burns to small children along with respiratory and environmental impacts from biomass fuel combustion.

Figure 2.6: Boiling is commonly known but unacceptable to the user

2.4.2 Solar Disinfection (SODIS)

Invented by a Professor at the American University of Beirut, Lebanon in 1982, solar disinfection has also proven a highly effective treatment option. SODIS Researchers at the Swiss

Federal Institute of Environmental Science and Technology (ETH-EAWAG/SANDEC) took up extensive studies of SODIS in 1991 and have demonstrated a high removal rate of a wide range of microbial contaminants. A simple technology, SODIS involves filling clear plastic bottles with contaminated water and exposing them to full sunlight for six hours (Figure 2.7). Sunlight treats the water through two synergetic mechanisms: 1) Radiation in the spectrum of UV (320-400nm); and 2) increased water temperature. If the water temperature rises above 50 ºC the process is three times faster (www.sodis.ch 2008).

SODIS remains a low-cost treatment – Pet bottles are widely available for reuse – that does not pollute the environment. Some noted drawbacks to this method include user acceptance issues such as the length of time to treat the water, the consumer's preference of drinking water temperature, and sustained behavior over an extended period of time. Also, if the turbidity of the source water is higher than 30 NTU, another process must be employed prior to SODIS to remove sediment or color.

Figure 2.7: SODIS inactivates microorganisms by UV and thermal treatment

2.4.3 Chlorination

Highly promoted by the Center for Disease Control, chlorination is an inexpensive method of water treatment that is very effective at neutralizing bacteria and viruses. Cited advantages include ease of use, cost effectiveness ($0.40-0.80/family/month), and the ability to treat large amounts of water at once (CAWST 2006). Usually utilized in the disinfection stage of treatment and probably employed as a guarantee for safe storage, it is unknown to what extent chlorination is used alone as a POU option. Overall, it faces serious challenges when considering user acceptance. To be adopted chlorination needs sustained behavior change that requires an immense amount of educational and promotional support. The simplicity of the treatment is also questionable; a specific dose of chlorine (usually found as a percentage in bleach) is required for a specific amount of water. This can be a difficult process for lesser educated people to perform. Not only do the physical characteristics of the treated water offer no apparent change but the water has an unusual smell and taste that users typically dislike. Furthermore, bleach or chlorine solution (Figure2.8) is not readily available in many local markets around the country, especially in rural areas .This makes it harder when introducing a product that is unfamiliar to the user.

Other limitations to chlorination include the long contact time required for treatment, need for low-turbid water to be most effective, non-effectiveness at killing protozoan cysts, and unknown carcinogenic effects caused from consuming complex chlorine-organic compounds over long periods of time (CAWST 2006).

Figure 2.8: Chlorine is cost-effective but not available in small market towns

2.4.4 Bio sand filtration

In laboratory and field tests the BSF consistently reduces bacteria, on average by 81-100% (Kaiser et al, 2002) and protozoa by 99.8-100% (Palamateer et al, 1999). However, initial research shows that BSFs remove less than 90% of indicator viruses. Since it does not provide complete removal of pathogens, recontamination of drinking water can occur in the storage phase. The technology has high user acceptability due to its ease of use, and provision of a physically improved and better tasting drinking water. Other benefits include sustainability since it can be produced locally from available materials, the convenience of a one-time installation with little maintenance required, a fast flow rate of up to 1.0 L/min, and a long product lifetime with no parts to replace. Some challenges to the technology involve the difficulty of transport – each concrete filter can weigh over 300 lbs empty – and a high initial cost.

2.5 Overall Biosand Filters performance

Overall, these studies of laboratories have shown that the Biosand filter removal performance:-

- > 97% of E. coli - an indicator of fecal contamination (Duke, 2006; Stauber, 2006)
- > 99% of protozoa and helminthes (Palmateer, 1999)
- 80-90% of viruses (Stauber, 2005)
- 50-90% of organic and inorganic toxicants (Palmateer, 1999)
- 90-95% of iron (Ngai, 2007)
- Most suspended sediments

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The methodology followed in this project was determined by the objective of the study and the hypotheses statements listed in Chapter 1. To achieve the objective of this project, a literature survey was conducted in order to identify and select the most used HWTS products. The steps taken to conduct the project and to obtain quantifiable results were as follows:

i. A literature review was performed on sustainable Biosand filter for the rural communities as well as the ethical basis for providing developing countries with the knowledge and means to employ sustainable water quality, particularly in rural communities.

ii. The long term performance of BSF can be evaluated according to durability and heavy duty plastic won't corrode, crack or break under normal use and no breakable or moving parts to wear out. Sustainable, simple technology and made mostly of sand.

iii. The data needed for the analysis was identified. Data was sought from the existing WHO standards and from the extensive literature reviews.

iv. The sources of data were identified. Sand, Coarse aggregate, and Gravels were acquired locally; ordinary Local Plastics and other materials are available in the industries.

v. Standard water quality testing such as Physical test, Chemical test and Biological test selected samples with various methods are measured.

vi. Analytical and descriptive statistics was used to assess the significance of the laboratory results sought.

vii. The biosand filter is best used as one step in a multi-barrier approach to safe drinking water. Different treatment methods remove different things from contaminated water. The most common low-cost methods used to filter the disinfect drinking water are: Mechanical trapping, Predation, Adsorption and Natural death.

viii. The biosand filter is constructed from locally available materials, One-time installation with low maintenance requirements; and long life (estimated >10 years) with no recurrent expenses

3.2 Biological Test

3.2.1 Microbial Tests

The performance of BSF is evaluated by microbial tests are used to removing indicator organisms. The concept of indicator organisms is the basis for most microbiological quality standards in water today. Pathogens in water are usually few in number and difficult to isolate. Instead of determining the actual concentrations of pathogens, indicator organism concentrations are often measured to determine the level of contamination in water. Indicator organisms are typically microbes that do not cause diseases themselves, but are found in conjunction and in higher concentrations than waterborne pathogens.

A microbial test can be used to find sources of contamination. Labs actively cultivating micro-organisms in a Petri dish when conducting microbial tests. Microbial tests check for the presence of potentially harmful microorganisms in a sample. A microbial test is a laboratory test that checks for the presence of microorganisms in a sample provided to the laboratory. Such testing is used for product safety, to look for signs of contamination in products that will be provide to the rural community, and for lab control, to confirm that the products and equipment being used in a lab are not contaminated with microorganisms.

There are strict requirements about the facilities where such products are processed and handled that are designed to reduce the risk of contamination, but even with careful adherence to standards and procedures, contaminants can creep in. A microbial test confirms that the products are safe to distribute.

a) Types of microbial testing methods

1. Qualitative or Presence/Absence (P/A) tests and
2. Quantitative/enumeration techniques.

1. Qualitative or Presence/Absence (P/A) tests

A presence/absence (P/A) test give a simple yes or no answer to whether certain bacteria are in a water sample, but does not indicate its quantity in the water. The advantage of these tests is that they are simple, inexpensive and sensitive.

The Presence/Absence (P/A) test, it gives a positive or negative response to total coliform as well as E.coli. This test is easy to perform: it only requires that the reactive medium, combined with 100 mL of sample and incubated for 24 to 48 hours at 35°C. The culture medium acts as the food source for the bacteria present in the water sample. During the incubation period, if bacteria reproduce in large numbers, resulting in a color change (from purple to yellow) of the liquid mixture, thus making their presence apparent. The analysis is modified to test for E.coli by using a reagent that fluoresces under long-wave ultraviolet light when E.coli is present.

2. **Quantitative/enumeration techniques**

Quantitative tests measure the amount of fecal coli form bacteria in CFU per 100mL water. One such method is the membrane filtration technique. This method requires filtering a sample of appropriate volume through a membrane filter of sufficiently small pore size to retain the organism(s) sought. Then the filter is placed on an appropriate agar medium, or pad saturated with an appropriate broth medium, and incubated. If the organisms sought are present, colonies will grow on the membrane filter. Colonies are examined and identified by size, color, shape. Typical colonies are counted and the number is reported as the number of colony forming units per 100 mL of sample. This technique is sensitive enough to detect 1 CFU/100mL.

Figure: 3.1 - Microbial test

3.2.2 Membrane Filtration

In membrane filtration, a thin film or semi permeable membrane is used to remove fine particulate matter from water. Desalination of salt water to produce potable water remains the primary use of membrane filtration.

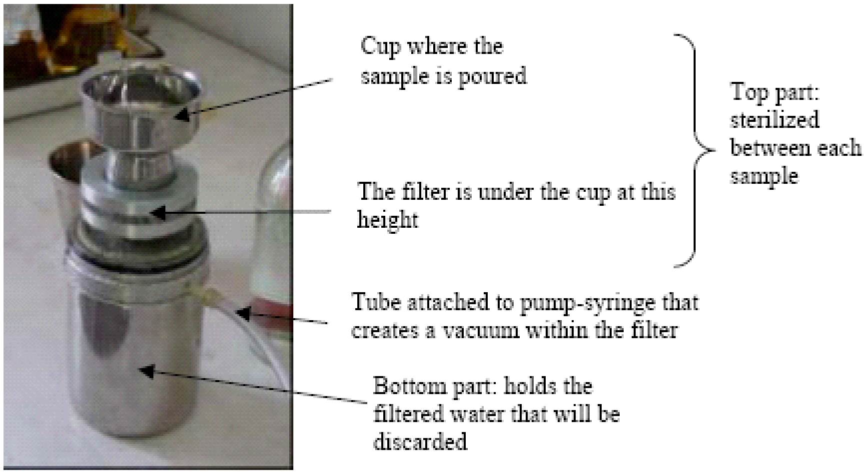

Figure:-3.2 membrane filtration

According to (CAWST 2006) there are four combinations of biological and mechanical processes to remove pathogens and other contaminants:

A. **Mechanical Trapping:** The primary process for removal of pathogens, mechanical trapping is the physical filtration of particles and organic material as they pass through the filter. Sand grain sizes are usually 0.1 – 1.0 mm and the pore spaces are usually less than this. Large materials such as grass, leaves, silt, or clay particles, along with large pathogens like parasites, helminthes and worms are trapped in the pore spaces. Smaller pathogens such as bacteria and viruses are trapped by the same process when they are attached to the larger particles. The filter removes 60-90% of all pathogens (over 99.9% of large pathogens) during this process.
B. **Predation**: Organic material is trapped at the surface of the fine sand and forms a complex biological layer, much like a pond or wetland ecosystem, where microorganisms grow and thrive. The composition of the top 1-3 cm varies depending on the source water. However, it will typically consist of a gelatinous biofilm of bacteria, fungi, protozoa, rotifer, and a range of aquatic insect larvae. These microorganisms gain nitrogen and carbon by consuming nutrients from the organics and other pathogens in the source water. Larger microorganisms consume smaller ones. Stronger ones consume weaker ones. Living ones consume dying ones. The series of predation is an active food chain within the biolayer. Oxygen is necessary for these aerobic organisms to survive.

This is provided by dissolved oxygen in the source water. (Intermittently operated sand filters differ from conventional designs in that additional oxygen is diffused through the static layer of water above the sand. If the water is too deep (>8cm) the oxygen cannot diffuse enough to get to the organisms.)

C. **Adsorption:** Pathogens and particles, attracted due to electrical and cohesive forces, attach themselves to one another and are thus trapped in pore spaces. Bacteria and viruses can also attach directly to the sand particles that compose the filter media. Once attached they are metabolized by the cells or inactivated by antiviral chemicals produced by organisms in the filter. As the biofilm starts to grow it tends to attract an increasing amount of particles to it. This takes place in the biological zone (or biolayer) of the filter, roughly 5-10 cm from the surface. After this depth biological activity curtails due to lack of nutrients and oxygen.

D. **Natural Death:** Different from predation, this refers to the “natural” die off rate or life expectancy of the microorganisms. If they are trapped long enough within the filter the pathogens will die from food scarcity or less than optimal temperatures before exiting the filter. This can also occur if the pause period is long enough – some organisms have life-spans of only a few hours – or if aerobic organisms are trapped deep within the filter where oxygen is not available.

3.3 Chemical Test

3.3.1 PH

A very important measurement in many liquid chemical processes (water supply agencies, industrial, pharmaceutical, manufacturing, food production, etc.) is that of pH: the measurement of hydrogen ion concentration in a liquid solution. A solution with a low pH value is called an "acid," while one with a high pH is called a "basic." The common pH scale extends from 0 (strong acid) to 14 (strong basic), with 7 in the middle representing pure water (neutral). According to PH measurement the required potable water is obtained ranging from 6.5-8.5. This shows that it is safe to drinking water for the community.

PH is an important variable in water quality assessment as it influences many biological and chemical processes within the water body and all issues associated with water supply and treatment processes.

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Figure 3.3: Measuring PH

A) WHO and EDWQ Guide lines Values

WHO and EDWQ guide lines Values are derived for many chemical constituents of drinking water. A guide line value normally represents the concentration of a constituent that does not result in any significant risk to health over a life time of consumption. A number of provisional guide line values have been established on the practical levels of treatment achievability or analytical achievability. The WHO and EDWQ Guide line values, based on risk assessments for naturally occurring chemicals that are significance for health in drinking water and shown in table below.

Table: 3.1 Drinking Water Quality Guidelines

PARAMETER	WHO GUIDELINE	EDWQ GUIDELINE
Arsenic	0.05mg/l	0.01mg/l
Barium	0.70mg/l	1.8mg/l
Cadmium	0.005mg/l	0.003mg/l
Chromium	0.05mg/l	0.1mg/l
Cyanide	0.1mg/l	0.07mg/l
Fluoride	1.5mg/l	3mg/l
Lead	0.05mg/l	0.02mg/l
Mercury	0.001mg/l	0.001mg/l
Nickel	0.1mg/l	0.01mg/l
Selenium	0.01mg/l	0.01mg/l
Nitrate	50mg/l	50mg/l
Nitrite	3mg/l	3mg/l

PARAMETER	WHO GUIDELINE	EDWQ GUIDELINE
Aluminum	0.2mg/l	0.4mg/l
Copper	1.0mg/l	2mg/l
Iron	0.3mg/l	0.4mg/l
Manganese	0.1mg/l	0.13mg/l
Zinc	5mg/l	6mg/l
Sodium	200mg/l	358mg/l
Chloride	250mg/l	533mg/l
Sulphate	400mg/l	483mg/l
TDS	1000mg/l	1776mg/l
Hardness	300mg/l	392mg/l
PH	6.5-8.5	6.5-8.5
Color	15TCU	22TCU
Turbidity	5NTU	7NTU
Taste	non-objectionable	non-objectionable
Temperature	non-objectionable	non-objectionable
Coli forms	Absent in 100ml	Absent

3.3.2 Florid Test

Fluoride is added to the water supply to reduce the incidence of dental caries. Hydrofluosilicic acid, sodium fluoride and sodium silicofluoride are the fluoride compounds that are commonly used for this purpose.

3.3.3 Iron Test

Irons are often present in groundwater and surface waters. Iron is more prevalent in groundwater. Iron found in groundwater originate when rock strata rich in iron are exposed to acidic water devoid of oxygen from anaerobic activity. Iron may also be present in surface waters, usually as organic complexes.

Iron can be a troublesome chemical in water supplies. Making up at least 5 percent of the earth's crust, iron is one of the earth's most plentiful resources. Rainwater as it infiltrates the soil and underlying geologic formations dissolves iron, causing it to seep into aquifers that serve as sources of groundwater for wells. Although present in drinking water, iron is seldom found at concentrations greater than 10 milligrams per liter (mg/L) or 10 parts per million. However, as little as 0.3 mg/l can cause water to turn a reddish brown color.

Iron is mainly present in water in two forms: either the soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. When exposed to air in the pressure tank or atmosphere, the water turns cloudy and a reddish brown substance begins to form. This sediment is the oxidized or ferric form of iron that will not dissolve in water.

3.3.4 Nitrate test

Nitrate test is used to know how much bacteria are present in an infant's stomach can convert nitrate to nitrite (NO2), a chemical which can interfere with the ability of the infant's blood to carry oxygen. As the condition worsens, the baby's skin turns a bluish color, particularly around the eyes and mouth. If nitrate levels in the water are high enough and prompt medical attention is not received, death can result. The federal drinking water standard recommend for nitrate is 10 mg/L of nitrate-nitrogen. It is tasteless, odorless, and colorless.

3.3.5 Sulfate test

Sulfate test used to know taste of water. If sulfate in water exceeds 250 mg/L, a bitter of medicinal taste may render the water unpleasant to drink. High sulfate levels may also corrode plumbing, particularly copper piping. In areas with high sulfate levels, plumbing materials more resistant to corrosion, such as plastic pipe, are commonly used.

3.4 Chemical Disinfection

3.4.1 Chlorination

Chlorine is an inexpensive treatment option used to improve water's taste and clarity while knocking out many microorganisms like bacteria and viruses. However, the process does have limitations. Guardia and cryptosporidium are generally resistant to chlorine unless it is used in higher doses than those generally preferred for treatment. The presence of these parasites may necessitate source water pre-treatment. Chlorine also removes substances like manganese, iron, and hydrogen sulphide, which can taint water taste. The liquid is simply diluted and then mixed with source water to effect disinfection.

These chlorination methods all require some time to work disinfection does not happen instantly. Required doses also change with variations in water quality so that source water monitoring, particularly of surface waters, is an important part of the treatment process. Chlorine treatment has some residual effects. Among the most noticeable is an unpleasant taste in treated water.

It is relatively simple and cheap to manufacture chlorine, and to transport it as sodium or calcium hypochlorite. It also requires little training to use. It use is also relatively simple, and treatment systems do not require extensive technical expertise. These qualities have made it popular as a point-of-use treatment even in impoverished areas despite its limitations in killing parasites. In conjunction with safe storage and water and food-handling practices, use of chlorination has produced significant drops in diarrheal disease in many locations.

3.5 Physical Tests

Physical tests are used to detect by the senses such as Turbidity, Colour, Odour and Tastes. There are several tests that can be made regarding different aspects of the filter. These tests are important in detecting possible operating problems with the filters.

3.5.1 Turbidity

Turbidity is a water quality parameter that quantifies the degree to which light traveling through a water column is scattered by suspended organic and inorganic particles. The scattering of light increases with the increased suspended load. Turbidity is commonly measured in Nephelometric Turbidity Units (NTU).

Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern. Turbidity can provide food and shelter for pathogens. If not removed, turbidity can promote re growth of pathogens in the distribution system, leading to waterborne disease outbreaks. Although turbidity is not a direct indicator of health risk, numerous studies show a strong relationship between removal of turbidity and removal of protozoa. The WHO guideline for the non-microbial turbidity level in drinking water is set at 5 NTU.

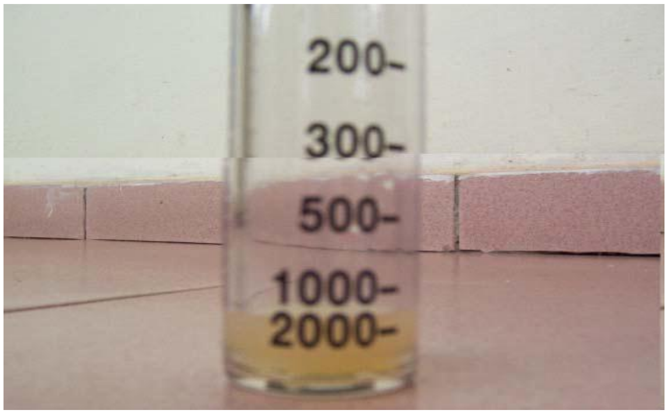

Figure: 3.4: Turbidity tube

Figure: 3.5: Pocket Turbid meter

The Turbid meter measures turbidity in the range from 0.1 to 400 NTU. It operates on the nephelometric principle of measurement, monitoring light scattered by the sample at 90° to the incident beam.

Turbidity of water is caused by suspended particles, primarily of clay, silt, organic matter, and microorganisms. In natural waters, turbidity can range from a few NTU to about 1,500 NTU.

While turbidity is not harmful by itself, excess turbidity hinders the efficiency of disinfection which can result in unsafe drinking water. Turbidity is a measure of the relative clarity or cloudiness of water. Turbidity is not a direct measure of suspended particles, but rather a general measure of the scattering and absorbing effect that suspended particles have on light. The principle behind the method is that a beam of light remains relatively undisturbed when transmitted through absolutely pure water; particles, when present, cause that light to be scattered and absorbed rather than transmitted. Similar to bacteriological indicator measurements, turbidity measurements are valuable indicators of water quality. High turbidity measurements or measurement fluctuations can be indicative of inadequate water treatment or a problem with water quality. The main benefits of using turbidity measurements as an indicator are that analysis is rapid and relatively inexpensive, and can be conducted continuously.

The sources and nature of turbidity are varied and complex and are influenced by the physical, chemical and microbiological characteristics of the water. Inorganic clays and silts and natural organic matter (decomposed plant and animal substances) make up the most common particulate constituents of water.

3.5.2 Standard simple processes for turbidity reduction

There are different processes useful for the reduction of turbidity. Some of these processes are: Sedimentation and Filtration

A. Sedimentation

Sedimentation can be a relatively slow process, as it is dictated by the terminal velocity of the particle. Therefore the extent of sedimentation achieved is dependent on the length of time the water is allowed to stand and the raw water quality. Considering one of the key features of the BSF is the fast flow rate of filtered water, the addition of a sedimentation process to the BSF as part of this modified design was considered to be cumbersome and likely to detract from the value of the filter.

B. Filtration

The BSF is a filtration system and modifications to the existing filtration process were considered to be the most feasible design alternatives to the single sand layer BSF. Analyzed several methods of filtration that could be included as part of the BSF to reduce turbidity.

3.6 Flow Rate

Flow rate measurement is useful at both the sand selection stage and the operations stage. At the sand selection stage, it indicates whether the sand in the filter is of an appropriate size. At the operations stage, it indicates that the filter requires maintenance.

The flow rate of a filter is determined by the effective size and uniform coefficient of the sand grains.

The recommended initial flow rate (for the purpose of sand selection) is 0.6liter per minute. The flow rates of the BSFs were found from measuring the time it takes to fill up a container of known volume. Only single measurements were taken. The flow rate depends on the head of the water. High flow rate would result if there is a high head gradient. To eliminate variations in flow rate due to the head gradient, flow rate measurements were started when the water level was about midway from the diffuser plate and the top of the filter. This ensured that comparison can be carried out uniformly across all the filters based only on the combined resistance to flow due to the sand, gravel and clogging of the filters. As the biological layer thickness sand as fine silts deposit on the topmost layer of sand, the flow rate of the filter will decrease.

As the filter clogs, its output decreases but its effectiveness in purifying water does not. In fact, the effectiveness is expected to increase, since slower flow rate allows longer contact time between the biofilm and the raw water. However, low output may not be sufficient to meet the needs of the family. If the water is coming out at a slight trickle, it is time to service the filter. The frequency of clogging is directly related to the quality of the water being treated. Very turbid waters, by surface water sources in rainy seasons, contain a large amount of fine silts, which are trapped in the uppermost layer of sand and biofilm. The higher the content of fine silts, the more quickly the filter will clog. Also, if the water contains a large amount of pathogens, the biofilm that feeds on this content will rapidly grow or thicken. This will also result in clogging at the top of the filter.

3.7 Evaluation of effectiveness and Performance of biosand filter

3.7.1 Effectiveness and performance of Previous filter

Slow sand filters operate at very low filtration rates, use very fine sand, and usually function without pre-chlorination. The low filtration rate results in long detention times in the water above the filter sand, and within the bed of the sand. The long detention time results in substantial biological life in the slow sand filtration process. Rapid filters have short detention times and are often operated with pre-disinfection so that no significant biological life is sustainable. Hence, rapid filters use physical straining to trap solids in the pores between sand particles. While rapid filtration can only remove particles larger than the void space between the sand particles, slow sand filters can remove particles smaller than the space between sand particles. Also, slow filtration particle removal occurs mainly at the surface of the sand bed with minor removal within the bed. Rapid filtration particle removal occurs mainly within the bed over a substantial depth.

In addition, rapid filters are cleaned every day or two when terminal head loss is reached. Backwashing a slow sand filter using the same method as in a rapid sand filter would create havoc with the biological layer because fluidizing of the bed would damage the bio film and disrupt the intricate interrelationships of sand and microscopic life. Slow sand filters usually are returned to operational status by scraping and removing the top layer of sand because that is where the clogging takes place. Compared to rapid sand filtration, there is a net savings of water as large quantities of backwash water are not required.

Rapid filters are suitable for large urban centers where land scarcity is an issue. Slow sand filters are suitable for developing countries and small rural systems, where sufficient land is available. Slow sand filtration is simpler to operate than rapid filtration, as frequent backwashing is not required. Therefore, in terms of level of operation and maintenance, rapid filtration requires a technically qualified operator whereas operating a slow filter requires little technical skills .Furthermore, rapid filtration typically requires the addition of coagulant chemicals whereas slow filtration does not.

Table: 3.2-comparing the effectiveness and performance of previous filter

Criteria	**Slow sand filter**	**Rapid sand filter**
Filtration rate	0.1m/h	0.45m/h
Water above top of sand	1.5m	1.5m
Sand depth	0.8m	0.8m
Retention time above sand	15 hr	9 min
Retention time in sand bed	3.2 hr	2 min
Cycle length	1-6 month	1-4 day
Sand effective Size	0.15-0.35mm	0.35-1mm
Sand coefficient of uniformity	1.5-3	1.2-1.7

3.7.2 Effectiveness and performance of current Biosand filter

The BSF is a household-scale slow sand filter but with some differences. A plastic BSF is 0.4-0.9m tall, and measures 0.30m along its inner edge. A slow sand filter usually has a height ranging from 3-5m and a width of 4-15m. The BSF also has a higher flow rate than a typical slow sand filter. The BSF is also different from a slow sand filter with respect to its design to sustain the biofilm during intermittent flow. Two elements of the design contribute to the preservation of the biofilm. First, the filter is designed to hold 5cm of water above the top surface of the sand column while at rest.

The 5cm resting water level is based on research performed to determine at what head height the biology receives the maximum oxygen while still being protected from incoming water. A constant aquatic environment is necessary for the organisms present in the layer to survive. However, the water layer cannot be too deep or oxygen will not diffuse and the microorganisms will suffocate. Second, a diffuser plate/basin blocks input water from disturbing the top layer of sand.

3.7.3 Comparison of the Concrete Rectangular BSF and the Plastic BSF

There are several design factors that would affect the performance &effectiveness of a BSF, such as sand size, sand depth, and surface loading rate. In general, the better performance is expected with smaller sand size (larger surface area) and longer period of time. As a result, the Plastic BSF has a surface loading rate that is above the upper value of that of the Concrete Rectangular BSF.

Table 3.3 Comparison of the Concrete BSF and the Plastic BSF

Concrete Biosand Filter	**Plastic Biosand filter**
Heavy to move place to place	Easy to move place to place
It requires high cost to construct	Low cost
Cracking is occurs	No cracking is occurs since it’s plastic
Not easily to maintain and operate	Easy to maintain and operate

From this we conclude that plastic biosand filter is better performance and effective to for the rural community to use easily.

Table 3.4 Comparison of the Concrete BSF and the Plastic BSF Design

	Container Volume (L)	Average cross section area (cm^2)	Sand depth (cm)	Maximum water standing depth (cm)	Surface loading rate (m3/m2/hr)	Design flow rate (L/hr)
Concrete BSF	47	512	46	34	0.23-0.70	12-36

Plastic BSF	> 50	258	42+/-2 Or 18 (+5/+10)	22	0.19	20

3.8 Materials

3.8.1 Storage Container with Lid

A safe storage container should be coupled with the BSF, and the vessel should be dedicated to use with BSF filtrate only and have a tight fitting lid to prevent contaminants from entering, people dipping in hands or contaminated utensils and animals causing contamination.

A lid is essential to prevent debris, insects and dirty hands from entering and contaminating the filter. The lid should cover the filter at all times, except when adding water or performing maintenance. The lid may be made of plastic material &it must be clean, must not contain gaps that insects might pass through and should be secured.

The purpose of the lid is to prevent contamination of the water and the media. It is essential to the correct operation of the filter. It should completely cover the opening of the filter and cannot be easily knocked off the filter.

3.8.2 Diffuser Plate

The diffuser plate can be made of various common materials such as metal, wood, or plastic. This flexibility in the choice of materials allows the tailoring of the diffuser plate according to which material is locally available and therefore the lowest cost. A main criterion for the choice of plastic is non corrosiveness. The diffuser plate must be kept in good condition to keep the force of pouring water from disturbing the layer. If the biological layer is disturbed, the effectiveness of the filter will be compromised and more significant numbers of harmful organisms may pass through the filter.

3.8.3 Sand and Gravel

The sand in the BSF is crucial to the filtration process of the BSF. If this layer is disturbed or damaged, the effectiveness of the filter will be compromised and more significant numbers of harmful organisms may pass through the filter.

Sand porosity is an important factor relative to the formation of the filter cake and the biologically active zone. Sand porosity depends on the size and shape of the grains. It increases with the size of the grains and with the homogeneity of grain size and shape. High porosity leads to high flow rate and low probabilities of collisions between particles in water and the sand grains. Low porosity will bring about low flow rate and clogging. Therefore, a moderate porosity is required for optimal operation of the BSF. The porosity is small enough to trap particles in the water and large enough to let the water through and allow some room for biological growth.

Filtration Sand **Gravel Particles**

Figure 3.6:-sand and gravel particles

i. Requirements

1. Hard, durable, angular grains free from loam, clay and organic matter. Angular grains Decrease porosity and increase resistance to flowing water.
2. An effective particle size of range of 0.5-1mm.

ii. Preparation

There are several steps to the preparation of the sand and gravel. Locating source of gravel and sand from a crushing operation is pure, clean and relatively uniform in size and shape. It requires the least preparation and is the best possible sand source. In the absence of a manufactured source, it is necessary to locate a natural hillside sand deposit. If there are no other choices, one could use riverbed sand. In addition, riverbed sand grains are more rounded and smooth (as opposed to angular) in their shape, which decreases the effectiveness in trapping contaminants. Sand from high on a riverbank where there is no visible contamination should be used in preference to river bottom sand.

3.8.4 Aggregates

Aggregates are particles of rock or equivalent (gravels, crushed stones and other materials) which, when mixed with cementing materials and water to make concrete and, form part or whole of an engineering or building structure. It also make alone as road base, back fill. Aggregates, both fine and coarse are important ingredients in concrete production.

The size of the coarse aggregate is <4.75mm.

Figure 3.7 Aggregate particles

3.9 Construction Procedure of BSF

A brief step-by-step overview of the construction procedure is given below: -

1. Sieve the gravel and sand
2. Wash the gravel and sand
3. Provide the filter container
4. After all the connections are dry, fill up the container to the top with water. Check for visual leakage from the outside, especially near the bulkhead fitting. Check the flow rate. This should be 0.3-0.5 L/min. If the flow rate is too fast, there may be a leakage in the pipe connection. Check to see if there is no flow when you close the two holes in the interior pipe using your fingers.
5. Construct the diffuser basin:

Purchase a plastic basin of the correct diameter to fit the plastic bucket. Heat a small nail (1-2 mm in diameter), and melt holes into the plate. The holes should be small and evenly distributed.

6. Filter installation:

a) Set the container on a flat and stable surface. The filter should not be moved or disturbed after installation.

b) Pour water into the filter bucket.

c) Slowly add gravel until it covers the interior PVC pipe. In this case it was 3 inches deep.

d) Add coarse sand on top of the gravel so that it would form a layer of 1.5 inches.

e) Add water until the normal water level.

f) Add fine sand until it is 2 inches below the standing water level.

Figure 3.8 Sieving sand

a. Wash the course aggregate and gravel

Tools Needed:

1. Buckets
2. Clean water (not biologically contaminated, if possible)
3. 2 glass jars

Steps:

1. Place a small amount of 12 mm (½”) gravel in a bucket (approximately 8 cm (3”) deep).
2. Put twice as much water in the bucket.
3. Using your hand, swirl the gravel around until the water becomes quite dirty.
4. Pour the dirty water out of the bucket.

5. Repeat the process until the water in your bucket stays clean.
6. Clean the rest of the 12 mm (½”) gravel, using the same method (a little at a time).
7. Repeat steps 1 through 6 for the 6 mm (¼”) gravel.
8. Put an even smaller amount of 0.7 mm (0.03”) sand in the bucket (approximately 5 cm(2”) deep).
9. Put double the amount of water in the bucket.
10. using your hand, swirl the sand around the bucket 10 times very quickly, making sure your fingers touch the bottom of the bucket and get all of the sand moving.
11. Quickly decant the dirty water.
12. Repeat steps 9 to 11 as many times as determined in the flow rate testing
13. Clean the rest of the sand using the same method (steps 8 through 12).
14. Place all of the media on a tarp or concrete surface in the sun to dry. This step is especially important if the media or the wash water might be biologically contaminated.
15. Store the media under tarps once it is dry.

Figure 3.9: Washing gravel

b. wash the sand

- Wash the sand as described in steps 8 to 11 above.
- As you wash, count the number of times that you decant your bucket.
- The first time you wash the sand, it is necessary to experiment with the washing procedure in order to determine the proper number of washes.
- To estimate if the sand has been washed adequately, put some sand in a glass jar with an equal amount of clear water. Put the lid on and swirl it. Looking from the side of the jar, 3-4 seconds after you stop swirling, you should be able to see the surface of the sand.

For the final test of the sand, install a biosand filter on site using your media, and test the flow rate. It should be 0.6 L/minute or less.

- If the flow rate is greater than 0.6 L/minute, the sand has been washed too much. You must decrease the number of times that you wash the sand. A flow rate that is too fast is not acceptable – the filter will not be effective.
- If the flow rate is less than 0.6 L/minute, the sand hasn't been washed enough. You must increase the number of times that you wash the sand. The filter will still function if the flow rate is too slow, but it may clog more often, requiring more frequent maintenance. If the flow rate is just slightly less than 0.6 L/minute, it can be left as is – as long as the flow rate isn't so slow that it is inconvenient for the user.
- Initially, it is a trial and error process – but that is why its important to count how many times you wash the sand, so that once you get the correct flow rate, you can repeat the same process.
- The media will vary so the number of times that you wash the sand will have to be adjusted periodically, but after some time you should develop the ability to know when the sand has been adequately washed, just by looking at the wash water in your bucket.

Figure 3.10 washing sand

c. Measuring the flow rate

Tools Needed:

1. Measuring container with 1 liter mark
2. Stopwatch
3. Bucket

Steps:

1. Fill the filter to the top with water.
2. Place your measuring container under the spout to collect the outlet water.
3. Measure the time it takes to fill the container to the 1 liter mark. The flow rate should be at a maximum of 0.6 L/minute (see table to the right to convert seconds per liter into liters per minutes).
4. If the flow rate is very slow (under approximately 0.2 L/minute, taking more than 5 minutes to fill the measuring container to 1 liter):
    - The filter will still work, but it may clog faster and more often, requiring more maintenance.
    - If it takes too long to get a pail of water, the user may not like the filter and may use untreated water
    - The flow rate can be improved by “swirling” the top layer of the sand and then scooping out the dirty water.
    - If a few “swirl & dumps” do not improve the flow rate substantially, the sand is either too fine or too dirty – you will have to rewash the sand.
5. If it takes less than 100 seconds to fill the measuring container to 1 litre, the flow rate is too fast:

- The filter may not function effectively.
- The media should be replaced with finer media (less washed).
- A less preferable option is to run a considerable amount of water through the filter until the flow rate decreases (due to the capture of finer particles and faster growth of the biolayer).

$$Q = \frac{V}{t}$$

Where: Q – The amount of flow rate

V – Volume of the water

T – Time taken

The flow rate through the filter decreases as the height of the water in the reservoir drops. As the water level reaches the diffuser, treated water may only drip out of the filter spout. It can take 40–90 minutes for the 20 litters in the reservoir to completely pass through the filter.

Figure 3.11: Measuring flow rate

3.10 The Effectiveness and Performance of the Project

On this method of study we summarize three tests. These tests are physical test, chemical test and micro biological tests. On physical test we measure turbidity. From turbidity measurements of the influent and effluent of the BSF, the turbidity removal in a BSF averaged 75% for all the BSFs that were tested. On average, 84% of the turbidity of the influent water was removed. In chemical test there is PH, fluoride, nitrate, sulphate, Iron are measured. From chemical test the biosand filter removal performance are 50-90% of organic and inorganic toxicants and 90-95% of iron. In microbiological test there is Membrane filtration test results showed that the BSF removed an average of 99.5% of total coli form after being in operation for 48hr. This verified that the BSF is a fairly effectives technology for the removal of total coli forms in water.

CHAPTER FOUR
DATA ANALYSIS AND RESULT

4.1 Introduction

This chapter deals with the analysis based on effectiveness and performance of BSFs, water treatment method and implementation of BSFs those listed in the literature review in addition to this laboratory test and results are included.

4.2 Analysis of Laboratory Tests

In the analysis of this test the following tests are done. These are physicals, chemical and microbiological tests.

4.2.1 Physical tests

Physical test are used to detect by the senses, namely turbidity, colour, taste, and odour. They are important in monitoring community water supplies because they may cause the water supply to be rejected and alternative (possibly poorer-quality) sources to be adopted and they are simple and inexpensive to monitor qualitatively in the field.

A. Taste and odour

Odours in water are caused mainly by the presence of organic substances. Some odours are indicative of increased biological activity; others may result from industrial pollution. Sanitary inspections should always include the investigation of possible or existing sources of odour, and attempts should always be made to correct an odour problem. Taste problems (which are sometimes grouped with odour problems) usually account for the largest single category of consumer complaints. As water should be free of objectionable taste and odour, it should not be offensive to the majority of the consumers. Odour and taste are associated with the presence of living microscopic organisms; or decaying organic matter including weeds, algae; or industrial wastes containing ammonia, phenols, halogens, hydrocarbons. While chlorination dilutes odour and taste caused by some contaminants, it generates a foul odour itself when added to waters polluted with detergents, algae and some other wastes.

B. Colour

Color in water may be caused by the presence of minerals such as iron and manganese or by substances of vegetable origin such as algae and weeds. Colour tests indicate the efficiency of the water treatment system. Colour in drinking-water may be due to the presence of coloured organic matter, e.g. highly coloured industrial wastes. Drinking-water should be colorless. For the purposes of surveillance of community water supplies, it is useful simply to note the presence or absence of observable colour at the time of sampling. Changes in the colour of water and the appearance of new colours serve as indicators that further investigation is needed.

C. Turbidity

Turbidity determination is used to evaluate the performance of water treatment plants**.** It is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates. It could be used to provide an estimation of the **TSS (Total Suspended Solids).** Turbidity is measured in NTU: **Nephelometric Turbidity Units**. The instrument used for measuring it is called nephelometer, colorimeter or turbid meter. No suspended solid present is a value of O NTU, while drinking water should be no more than 5 NTU.

Turbidity found in water is because of suspended solids and colloidal matter. It may be due to eroded soil caused by the growth of micro-organisms. High turbidity makes filtration expensive.

Turbidity is the technical term referring to the cloudiness of a solution and it is a qualitative characteristic which is imparted by solid particles obstructing the transmittance of light through a water sample. Turbidity often indicates the presence of dispersed and suspended solids like clay, organic matter, silt, algae and other microorganisms.

Figure4.1 Turbid meter

Material, tools and Apparatus required to measure turbidities are:-Turbidity meter, Sample cell, Standard flasks, Funnel, Wash bottle, Tissue papers

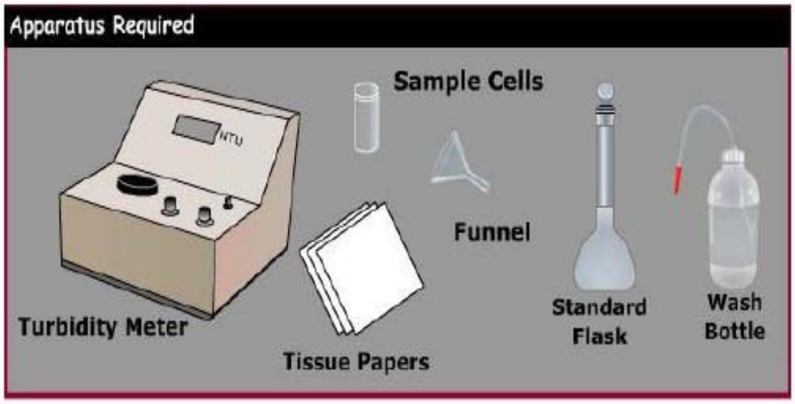

Figure 4.2 apparatus required for turbidity test

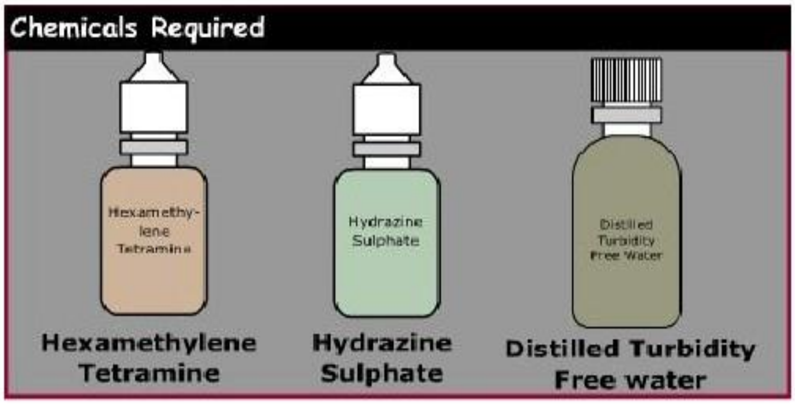

Figure 4.3 chemical required for turbidity test

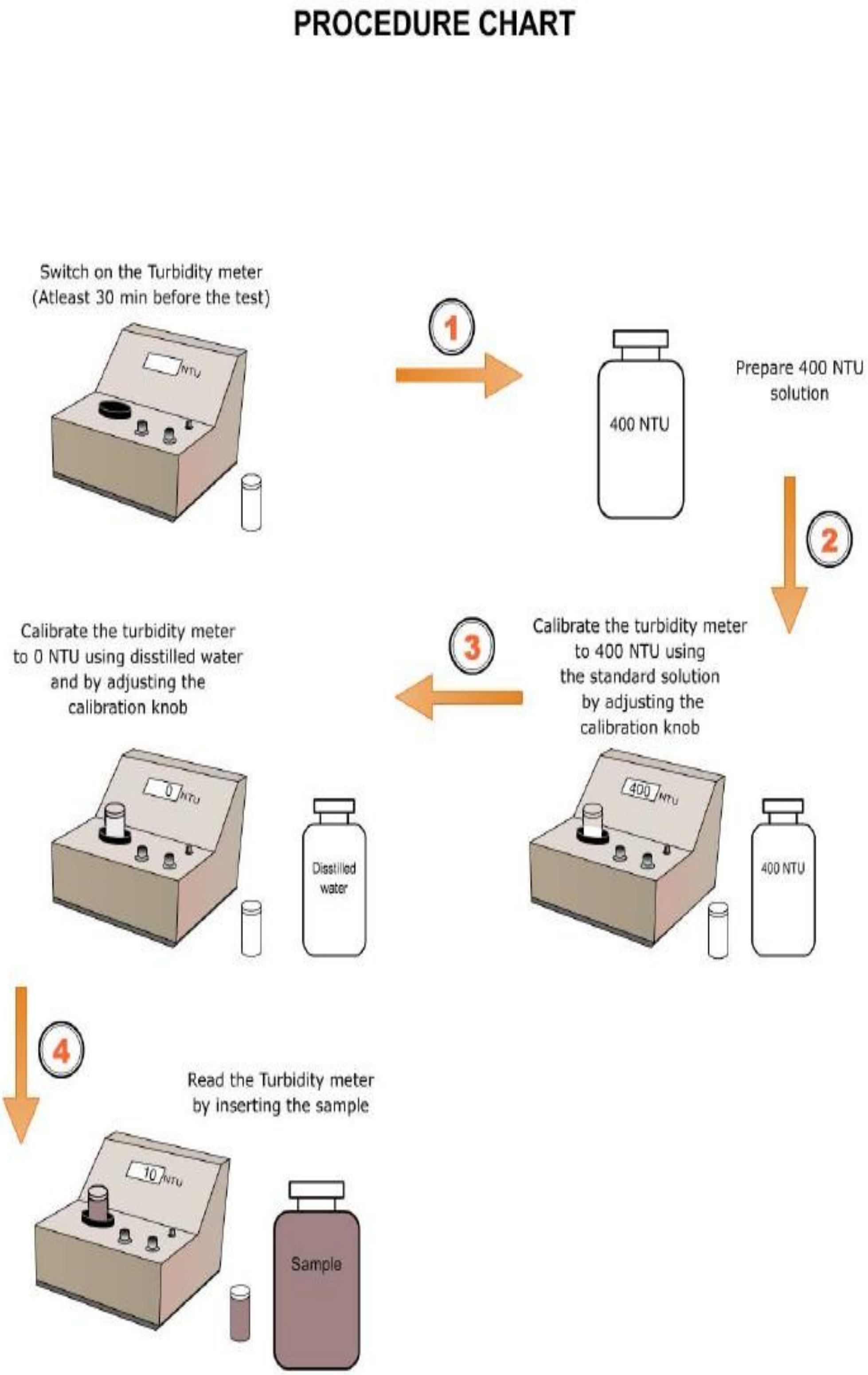

Figure 4.4 Turbidity procedure chart

A) Sample Handling and Preservation

Water samples should be collected in plastic cans or glass bottles. All bottles must be cleaned thoroughly and should be rinsed with turbidity free water. Volume collected should be sufficient to insure a representative sample, allow for replicate analysis (if required), and minimize waste disposal. No chemical preservation is required. Keep the samples at 4°C. Samples to freeze.

Analysis should begin as soon as possible after the collection. If storage is required, samples maintained at 4°C may be held for up to 48 hours.

a) **Precautions**

The following precautions should be observed while performing the experiment:

The presence of colored solutes causes measured turbidity values to be low. Precipitation of dissolved constituents (for example, Fe) causes measured turbidity values to be high.

Light absorbing materials such as activated carbon in significant concentrations can cause low readings.

The presence of floating debris and coarse sediments which settle out rapidly will give low readings. Finely divided air bubbles can cause high readings.

b) Measuring procedure

i. Place the zero adjusting assay bottle loaded with zero turbidity water into the sample holder and make sure that the scale line of the assay bottle is aligned with the white position line on the sample holder, and then cover with the light shading cover;
ii. Turn the "zero adjust" button a little after getting a stable reading, make it display as nominal value;
iii. Load the standard solution into the sample holder adopting the same method, and turn the "correction" button, to make it indicate the nominal value;
iv. Repeat steps i, ii and iii, make sure the zero point and corrected value correct and reliable;
v. Put into assay bottle and note dawn the turbidity value of the water sample upper the reading gets stable;
vi. The instrument will automatically close dawn 15 minutes ever since start- up.

c) Calibration of turbidity meter

Using the standard solution calibrate the instrument. The instrument is having four knobs, out of which the two knobs in the bottom is the set zero knob, this is for setting the instrument to zero. The one which is there in the top left hand side is the calibration knob, used for the calibration. The other one in the top is the knob for setting the detection range. It is adjusted to 1000 NTU range.

Step 1

To the sample cells, add turbidity free distilled water up to the horizontal mark, wipe gently with soft tissue. Place it in the turbidity meter such that the vertical mark in the sample cell should coincide with the mark in the turbidity meter and cover the sample cell. Now using the set zero knob, adjust the reading to zero.

Step 2

According to our need, prepare a standard solution. In this case, a 200 NTU solution is prepared by diluting the standard 4000 NTU solution and added to the sample cells, up to the horizontal mark, wipe gently with soft tissue. Place it in the turbidity meter such that the vertical mark in the sample cell should coincide with the mark in the turbidity meter and cover the sample cell.

If the instrument is not showing 200 NTU, using the calibration knob adjust the reading to 200 NTU.

Repeat the procedure for two / three times.

Now the instrument is calibrated.

d) Testing of water sample

To the sample cells, add sample water up to the horizontal mark, wipe gently with soft tissue and place it in the turbidity meter such that the vertical mark in the sample cell should coincide with the mark in the turbidity meter and cover the sample cell.

Check for the reading in the turbidity meter. Wait until you get a stable reading.

The turbidity of the given water sample is 8.4 NTU.

e) Calculation

For determining the Turbidity of the given water sample the readings are required to be tabulated.

Table 4.1:-Turbidity measurement before treatment in case of woliso bedessa rural area

Sample	**Temperature of sample (°C)**	**Turbidity (NTU)**
1.bore hole water	27	70
2.river water	27	156
3.lake water	27	187.5

For sample 1 the temperature of the sample is 27°C and turbidity value 70 NTU

For sample 2 the temperature of the sample is 27°C and the turbidity value 156. NTU

For sample 3 the temperature of the sample is 27°C and obtained turbidity value is 187.5 NTU

Table 4.2:-Turbidity measurement after treatment in case of woliso bedessa rural area

Sample	**Temperature of sample (°C)**	**Turbidity (NTU)**
1.bore hole water	27	5.3
2.river water	27	6.5
3.lake water	27	7

4.2.2 Chemical tests

In chemical test we measure the PH of fluoride, nitrate, sulphate, iron**.**

A.PH

PH is used to know the hardness, presence of a selected group of chemical parameters, biocides; highly toxic chemicals. PH is a measure of hydrogen ion concentration. It is an indicator of relative acidity or alkalinity of water. Values of 9.5 and above indicate high alkalinity while values of 3 and below indicate acidity. Low pH values help in effective chlorination but cause problems with corrosion. Values below 4 generally do not support living organisms in the marine environment. Drinking water should have a pH between 6.5 and 8.5.

B.Fluoride test

Fluoride test is important to know how much fluoride concentration is found in water. Before treatment, In our laboratory test fluoride of bore hole is 1.5mg/l, river water is 0.05mg/l, lake water is 2.5mg/l. after treatment fluoride of bore hole is 1.2 mg/l, river water is 0.01mg/l, lake water is 2.13mg/l.

C. Iron test

Iron test is important to know how much iron concentration is found in water. Before treatment, In our laboratory test iron of bore hole is 1.5mg/l, river water is 2.84mg/l, lake water is 4.97mg/l. after treatment fluoride of bore hole is 0.96 mg/l, river water is 1.89mg/l, lake water is 2.47mg/l.

D.Nitrate test

Nitrate test is used to know how much bacteria are present in an infant's stomach can convert nitrate to nitrite (NO2), a chemical which can interfere with the ability of the infant's blood to carry oxygen. As the condition worsens, the baby's skin turns a bluish color, particularly around the eyes and mouth. If nitrate levels in the water are high enough and prompt medical attention is not received, death can result. The federal drinking water standard recommend for nitrate is 10 mg/L of nitrate-nitrogen. It is tasteless, odorless, and colorless.

E. Sulphate test

Sulphate test used to know taste of water. If sulfate in water exceeds 250 mg/L, a bitter of medicinal taste may render the water unpleasant to drink. High sulfate levels may also corrode plumbing, particularly copper piping. In areas with high sulfate levels, plumbing materials more resistant to corrosion, such as plastic pipe, are commonly used.

i. Apparatus and chemicals required

Materials and apparatus required are PH meter, Standard flasks**,** Magnetic Stirrer, Funnel**,** Beaker**,** Wash Bottle**,** Tissue Paper and Forceps

Chemicals required: - Buffers Solutions of pH 4.01, 7.0 and 9.2, Potassium Chloride and Distilled Water

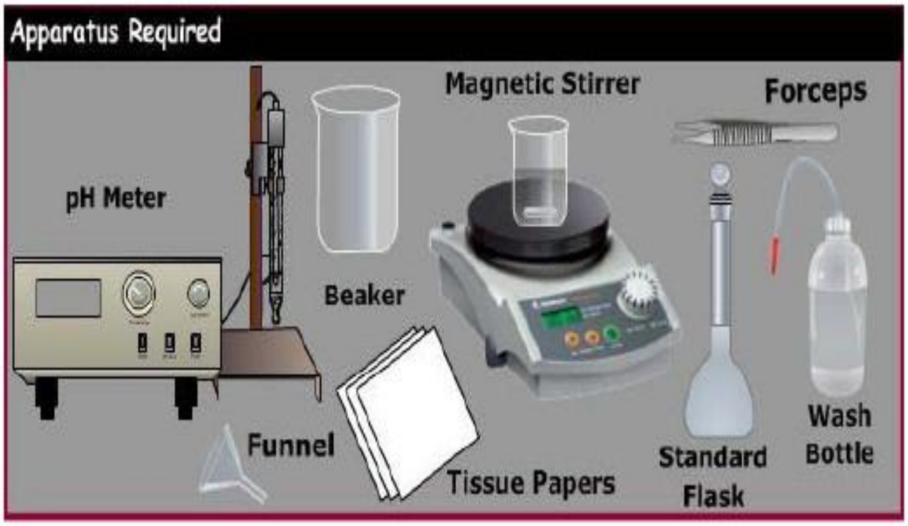

Figure 4.5 apparatus required for PH

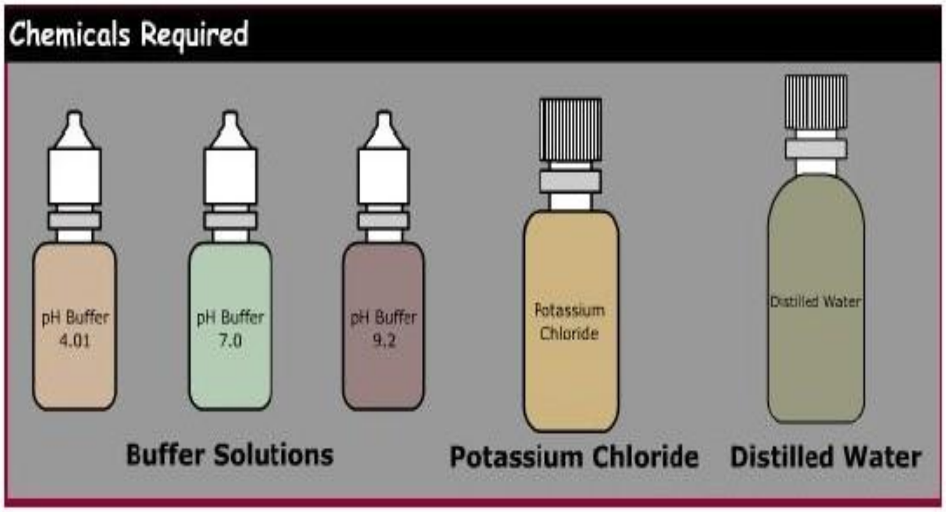

Figure 4.6 chemicals required for PH

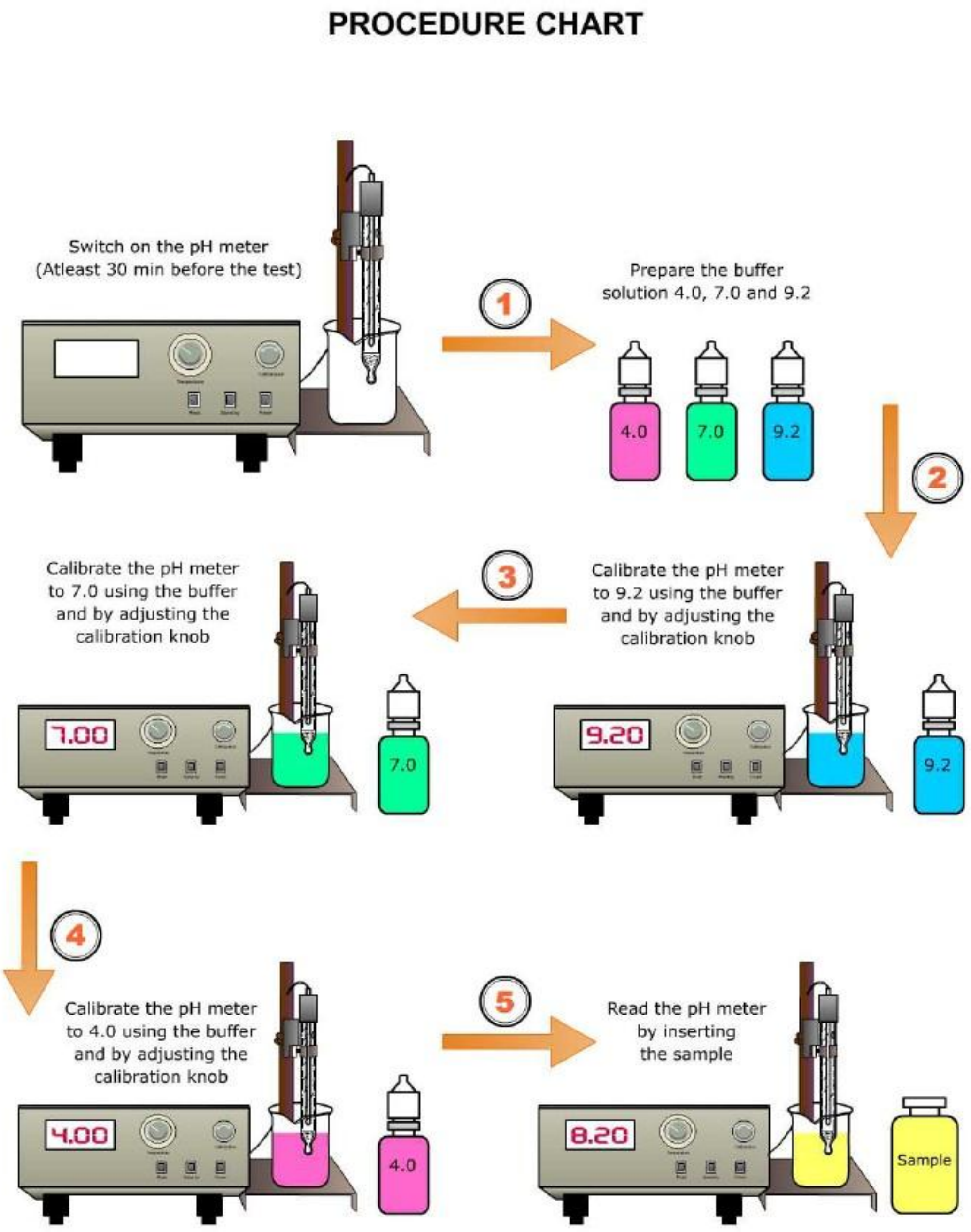

Figure 4.7: PH procedure chart

i. Procedures to determine PH value

Three major steps are involved in the experiment. These are Preparation of Reagents, Calibrating the Instrument and Testing of Sample

a. Preparation of Reagents

1. **Buffer Solution of pH 4.0**

- Take 100 mL standard measuring flask and place a funnel over it.
- Using the forceps carefully transfer one buffer tablet of pH 4.0 to the funnel.
- Add little amount of distilled water, crush the tablet and dissolved it.
- Make up the volume to 100 mL using distilled water.

2. **Buffer Solution of pH 7.0**

- Take 100 mL standard measuring flask and place a funnel over it.
- Using the forceps carefully transfer one buffer tablet of pH 7.0 to the funnel.
- Add little amount of distilled water, crush the tablet and dissolved it.
- Make up the volume to 100 mL using distilled water.

3. **Buffer Solution of pH 9.2**

- Take 100 mL standard measuring flask and place a funnel over it.
- Using the forceps carefully transfer one Buffer tablet of pH 9.2 to the funnel.
- Add little amount of distilled water, crush the tablet and dissolved it.
- Make up the volume to 100 mL using distilled water.

b. Calibrating the instrument

Using the buffer solutions calibrate the instrument.

Step 1

In a 100 mL beaker take pH 9.2 buffer solution and place it in a magnetic stirrer, insert the Teflon coated stirring bar and stir well.

Now place the electrode in the beaker containing the stirred buffer and check for the reading in the pH meter.

If the instrument is not showing pH value of 9.2, using the calibration knob adjust the reading to 9.2.

Take the electrode from the buffer, wash it with distilled water and then wipe gently with soft tissue.

Step 2

In a 100 mL beaker take pH 7.0 buffer solution and place it in a magnetic stirrer, insert the teflon coated stirring bar and stir well.

Now place the electrode in the beaker containing the stirred buffer and check for the reading in the pH meter.

If the instrument is not showing pH value of 7.0, using the calibration knob adjust the reading to 7.0.

Take the electrode from the buffer, wash it with distilled water and then wipe gently with soft tissue.

Step 3

In a 100 mL beaker take pH 4.0 buffer solution and place it in a magnetic stirrer, insert the teflon coated stirring bar and stir well.

Now place the electrode in the beaker containing the stirred buffer and check for the reading in the pH meter.

If the instrument is not showing pH value of 4.0, using the calibration knob adjust the reading to 4.0.

Take the electrode from the buffer, wash it with distilled water and then wipe gently with soft tissue.

Now the instrument is calibrated.

c. Testing of sample

In a clean dry 100 ml beaker take the water sample and place it in a magnetic stirrer, insert the Teflon coated stirring bar and stir well.

Now place the electrode in the beaker containing the water sample and check for the reading in the pH meter. Wait until you get a stable reading.

The pH of the given water sample is 8.84

Take the electrode from the water sample, wash it with distilled water and then wipe gently with soft tissue

d. Calculation

To determine the value of pH of the given water sample the readings obtained are required to be tabulated

Table 4.3:-The PH before treatment in case of woliso bedessa rural area

Sample no	**Temperature (ºC)**	**PH**	**Fluoride (mg/l)**	**Iron (mg/l)**	**Nitrate (mg/l)**	**Sulfate (mg/l)**
1.bore hole water	27	7.86	0.96	0.06	1.3	16
2.river water	27	8.00	0.01	2.84	11.7	41
3.lake water	27	8.56	0.03	4.56	18.54	87

Table 4.4:- The PH after treatment in case of woliso bedessa rural area

Sample no	**Temperature (ºC)**	**PH**	**Fluoride (mg/l)**	**Iron (mg/l)**	**Nitrate (mg/l)**	**Sulfate (mg/l)**
1.bore hole water	27	7.86	0.96	0.06	1.3	16
2.river water	27	7.93	0.009	2.69	10.53	17
3.lake water	27	8.15	0.01	2.54	4.54	27m

4.2.3 Microbiological test

Bacteriological analysis can prove is that, at the time of examination, contamination or bacteria indicative of faecal pollution, could or could not be demonstrated in a given sample of water using specified culture methods.

Most microbiological analysis for drinking water will provide the numbers of Total Viable Bacteria, Total Coli forms and *E. coli* present in 100 ml of water. Total Viable Bacteria have no direct relation to faecal contamination and are not a health risk, however they provide an indication of general microbiological content of the water. Total Coliforms refer to a large group of bacteria that can be of faecal or non-faecal origin. Many of the non-faecal organisms grow naturally in the environment, including water. Total Coli forms do not present a direct health risk, but can provide information on the efficiency of drinking water disinfection.

E. coli present in drinking water means that human or animal faeces have contaminated the water. Faeces can harbour a number of other pathogenic, or disease causing, organisms. If your drinking water sample is positive for E. coli it is recommended that water used for drinking and oral hygiene is boiled and cooled prior to use, or that bottled water is used for that purpose, until repeat sampling indicates that your drinking water is free of E. coli.

a) Membrane-filtration method

In the membrane-filtration (MF) method, a minimum volume of 10 ml of the sample (or dilution of the sample) is introduced aseptically into a sterile or properly disinfected filtration assembly containing a sterile membrane filter (nominal pore size 0.2 or 0.45mm). A vacuum is applied and the sample is drawn.

Table 4.5: Typical sample volumes for membrane-filtration analysis

Sample type	**Sample volume (**colony/100ml)
Treated drinking-water	100
Partially treated drinking-water	10–100
Protected source water or groundwater	10–100
Surface water and water from open wells	0.1–100

Volumes less than 10 ml should be added to the filtration apparatus after addition of at least 10ml of sterile diluents to ensure adequate dispersal across the surface of the membrane filter.

Through the membrane filter all indicator organisms are retained on or within the filter, which is then transferred to a suitable selective culture medium in a Petri dish. Following a period of resuscitation, during which the bacteria become acclimatized to the new conditions, the Petri dish is transferred to an incubator at the appropriate selective temperature where it is incubated for a suitable time to allow the replication of the indicator organisms. Visually identifiable colonies are formed and counted, and the results are expressed in numbers of “colony forming units” (CFU) per 100 ml of original sample.

This technique is inappropriate for waters with a level of turbidity that would cause the filter to become blocked before an adequate volume of water had passed through. When it is necessary to process low sample volumes (less than 10 ml), an adequate volume of sterile diluents must be used to disperse the sample before Filtration and ensure that it passes evenly across the entire surface of the membrane filter. Typical sample volumes for different water types are shown in Table 4.3. Where the quality of the water is totally unknown, it may be advisable to test two or more volumes in order to ensure that the number of colonies on the membrane is in the optimal range for counting (20–80) colonies per membrane.

b) Membrane filtration laboratory procedure

1. The sample volume is taken based on the type of source as tap water (treated) 100mlof the sample is taken and filtered through sterilized filtration unit (filtration flask are sterilized).
2. Membrane filter 0.45ucm is taken out aseptically and placed in the filtration unit.
3. The membrane filter is taken aseptically placed in the petri-dish which contains media.
4. The Petri-dish is labeled with following information:-Name of the analysis, Date of analysis, Time, Sample number and Sample volume.
5. The Petri –dish is incubated for 24hr at 37 ºC for total coli form, 44 ºC for faecal coliform**.**
6**.** After incubation time the Petri dishes are taken out for counting under colony counter.

c) Bacteriological Results

Table: 4.6 Bacteriological results before treatment in case of woliso bedessa rural area

Sample type(ml)	**Feacal coli form** (colony/100ml)	**Total coli form** (colony/100ml)
Bore hole water	0.93	1.5
River water	10	12
Lake water	11	15

Table: 4.7 Bacteriological results after treatment in case of woliso bedessa rural area

Sample type(ml)	**Feacal coli form** (colony/100ml)	**Total coli form** (colony/100ml)
Bore hole water	0.1	0.25
River water	0.02	0.03
Lake water	0.5	0.7

4.3 Summary on the effectiveness and performance of BSF based on their test

Overall, these studies of laboratories have shown that the biosand filter removal performance:-

- > 97% of E. coli - an indicator of fecal contamination
- > 99% of protozoa and helminthes
- 80-90% of viruses
- 50-90% of organic and inorganic toxicants
- 90-95% of iron
- Most suspended sediments

Figure 4.8 Summary of BSF effectiveness

	Bacteria	Viruses	Protozoa	Helminthes	Turbidity
Lab test	Up to 98.5%	70 – 99%	>99.9%	Up to 100%	95% <8NTU

From this result we deduce that biosand filter have good performance and effective by removing pathogens.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Overview

This chapter generalizes the objective, literature review, methodology, data analysis and test result of the project. This will be described on how to investigate effectiveness and performance of BSFs. Basically, it can be concluded that all objectives stipulated in Chapter one have been successfully achieved. These four objectives were: -to evaluate the long term performance of the BSF, to determine the ability of the Biosand filter to reduce concentrations of total Coli forms and E. coli in water, to determine the performance of the Biosand filter to reduce household diarrheal disease and construct a modified plastic BSF that would important for community water treatment.

5.2 Conclusion

Water is essential to sustain life, and when supplied as drinking water to consumers, a satisfactory quality must be maintained so that, provision of water, sanitation and good hygiene services are vital for the protection and development of human resources. Though BSF is much better than surface water in terms of biological quality, lack of source protection and inefficient treatment, waste management and sewerage system problem, poorly designed pit latrines and poor hygienic practice at the households affect the quality of the water. Therefore, assessment of bio-sand filter (BSF) and microbiological quality of drinking water from sources to house hold in selected communities of rural areas.

The BSF is modified forms of conventional slow sand filter (SSF) in that there is typically no pretreatment or backwashing and operation is simple, with gravity-driven rather than mechanical pressure filtration. As a result, this technology is effective and sustainable in the long term. Their ease of construction and simplicity of operation make them more sustainable than most competing systems.

From turbidity measurements of the influent and effluent of the BSF, the turbidity removal in a BSF averaged 75% for all the BSFs that were tested. On average, 84% of the turbidity of the influent water was removed. The average effluent turbidity was less than 5 NTU, which are the WHO maximum standards for drinking water.

From presence/absence tests, BSFs removes total coli form 99.5 after being operated for 48hr.As these results were not indicative of the effectiveness of the BSF at removing bacteria, further tests were carried out on a plastic BSF to evaluate the effectiveness of the filter. Membrane filtration results showed that the BSF removed an average of 99.5% of total coli form after being in operation for 48hr. This verified that the BSF is a fairly effectives technology for the removal of total coli forms in water.

The microbial tests are used to evaluate the performance of the BSF in removing indicator organisms. Microbial tests check for the presence of potentially harmful microorganisms in a sample. A microbial test is a laboratory test that checks for the presence of microorganisms in a sample provided to the laboratory. Flow rate measurements of the effluent water from the BSFs have an average of 0.625L/s, which means that the BSF could provide an adequate supply of drinking water for a household community water treatment. Overall, these studies of laboratories have shown that the biosand filter removal performance:-Biosand filter can remove, > 97% of E. coli - an indicator of fecal contamination, > 99% of protozoa and helminthes 80-90% of viruses, 50-90% of organic and inorganic toxicants, 90-95% of iron and Most suspended sediments.

5.3 Recommendation

Based on the result of the laboratory analysis the effectiveness removal of total coli forms, reduction of turbidity and high flow rate the BSF technology to be adopted on a large scale for rural community water treatment. However, these needs to go hand-in-hand with a monitoring plan to ensure correct construction, operation and maintenance procedures are followed. The monitoring plan is necessary for operation and maintenances of Biosand filters. Other drawbacks to the system should also be addressed. For example, pretreatment of higher turbidity water in the rainy season is necessary to reduce the silt/clay loading which would clog up the filter.

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APPENDIX

Drinking Water Quality Guidelines

PARAMETER	WHO GUIDELINE	EDWQ GUIDELINE
Arsenic	0.05mg/l	0.01mg/l
Barium	0.70mg/l	1.8mg/l
Cadmium	0.005mg/l	0.003mg/l
Chromium	0.05mg/l	0.1mg/l
Cyanide	0.1mg/l	0.07mg/l
Fluoride	1.5mg/l	3mg/l
Lead	0.05mg/l	0.02mg/l
Mercury	0.001mg/l	0.001mg/l
Nickel	0.1mg/l	0.01mg/l
Selenium	0.01mg/l	0.01mg/l
Nitrate	50mg/l	50mg/l
Nitrite	3mg/l	3mg/l

PARAMETER	WHO GUIDELINE	EDWQ GUIDLINE
Aluminum	0.2mg/l	0.4mg/l
Copper	1.0mg/l	2mg/l
Iron	0.3mg/l	0.4mg/l
Manganese	0.1mg/l	0.13mg/l
Zinc	5mg/l	6mg/l
Sodium	200mg/l	358mg/l
Chloride	250mg/l	533mg/l
Sulphate	400mg/l	483mg/l
TDS	1000mg/l	1776mg/l
Hardness	300mg/l	392mg/l
PH	6.5-8.5	6.5-8.5
Color	15TCU	22TCU
Turbidity	5NTU	7NTU
Taste	non-objectionable	non-objectionable
Temperature	non-objectionable	non-objectionable
Coli forms	Absent in 100ml	Absent

WOLISO POLY TECHNIQUE COLLEGE

WATER QUALITY LABORATORY

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RESULT OF MICROBIOLIGICAL ANALYSIS

Analysis Start Date: 28/05/2015 **Analysis Stop Date: 30/05/2015**

No.	Source	Total Coliform (cfu/100ml)		Faecal Coliform (cfu/100ml)	
		Before	After	Before	After
1	Bore Hole Water	1.5	0.5	0.93	0.1
2	River Water	12	0.03	10	0.02
3	Lake Water	15	0.7	11	0.5
4	Tap Water	0	0	0	0

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Mengistu Gadisa

(Officer Laboratory Service)

DETERMINATION OF TURBIDITY

DATA SHEET

Date Tested: May 28, 2015

Tested By: Mangistu Gadisa

Project Name: BSF Lab

Sample No. : T_1, T_2, T_3

Sample Location T_1: Bedesa Koricha Woreda

Sample Description: Bore Hole Water

Sample 1 bore hole water to treated water.

Sample Location $T_{2:}$ Chitu Woreda

Sample Description: River Water

Figure sample 2 river water to treated water

Sample Location $T_{3:}$ Wenchi Woreda

Sample Description: Lake Water

Figure of sample 3 Filtration of lake water to treated water

TABULATION

Sample No.	Temperature of Sample (°c)	Turbidity (NTU)	
		Before	After
T_1	27	70	5.3
T_2	27	156	6.5
T_3	27	187.5	7

Result: -

The turbidity of the given sample T_1= 5.3 NTU

The turbidity of the given sample T_2= 6.5 NTU

The turbidity of the given sample T_3= 7 NTU

DETERMINATION OF PH

DATA SHEET

Date Tested: May 28, 2015

Tested By: Mangistu Gadisa

Project Name: BSF Lab

Sample No. : PH_1, PH_2, PH_3

Sample Location PH_1: Bedesa Koricha Woreda

Sample Description: Bore Hole Water

Sample Location $PH_{2:}$ Chitu Woreda

Sample Description: River Water

Sample Location $PH_{3:}$ Wenchi Woreda

Sample Description: Lake Water

TABULATION

Sample No.	Temperature of Sample (°c)	PH	
		Before	After
PH_1	27	7.86	7.86
PH_2	27	8.00	7.93
PH_3	27	8.56	8.15

Result: -

The PH of the given sample PH_1= 7.86

The PH of the given sample PH_2= 7.93

The PH of the given sample PH_3= 8.15

DETERMINATION OF FLORIDE

DATA SHEET

Date Tested: May 28, 2015

Tested By: Mangistu Gadisa

Project Name: BSF Lab

Sample No. : F_1, F_2, F_3

Sample Location F_1: Bedesa Koricha Woreda

Sample Description: Bore Hole Water

Sample Location $F_{2:}$ Chitu Woreda

Sample Description: River Water

Sample Location $F_{3:}$ Wenchi Woreda

Sample Description: Lake Water

TABULATION

Sample No.	Temperature of Sample (°c)	Fluoride Test Result (mg/L)	
		Before	After
F_1	27	0.96	0.96
F_2	27	0.01	0.009
F_3	27	0.03	0.01

Result: -

The fluoride of the given sample F_1= 0.96 mg/L

The fluoride of the given sample F_2= 0.009 mg/L

The fluoride of the given sample F_3= 0.01 mg/L

DETERMINATION OF IRON

DATA SHEET

Date Tested: May 28, 2015

Tested By: Mangistu Gadisa

Project Name: BSF Lab

Sample No. : I_1, I_2, I_3

Sample Location I_1: Bedesa Koricha Woreda

Sample Description: Bore Hole Water

Sample Location $I_{2:}$ Chitu Woreda

Sample Description: River Water

Sample Location $I_{3:}$ Wenchi Woreda

Sample Description: Lake Water

TABULATION

Sample No.	Temperature of Sample (°c)	Iron Test Result (mg/L)	
		Before	After
I_1	27	0.06	0.06
I_2	27	2.84	2.698
I_3	27	4.56	2.54

Result: -

The Iron of the given sample I_1= 0.06 mg/L

The Iron of the given sample I_2= 2.698 mg/L

The Iron of the given sample I_3= 2.54 mg/L

DETERMINATION OF NITRATE

DATA SHEET

Date Tested: May 28, 2015

Tested By: Mangistu Gadisa

Project Name: BSF Lab

Sample No. : N_1, N_2, N_3

Sample Location N_1: Bedesa Koricha Woreda

Sample Description: Bore Hole Water

Sample Location $N_{2:}$ Chitu Woreda

Sample Description: River Water

Sample Location $N_{3:}$ Wenchi Woreda

Sample Description: Lake Water

TABULATION

Sample No.	Temperature of Sample (°c)	Nitrate Test Result (mg/L)	
		Before	After
N_1	27	1.3	1.3
N_2	27	11.7	10.53
N_3	27	18.54	4.54

Result: -

The nitrate of the given sample N_1= 1.3 mg/L

The nitrate of the given sample N_2= 10.53 mg/L

The nitrate of the given sample N_3= 4.54 mg/L

DETERMINATION OF SULFATE

DATA SHEET

Date Tested: May 28, 2015

Tested By: Mangistu Gadisa

Project Name: BSF Lab

Sample No. : S_1, S_2, S_3

Sample Location S_1: Bedesa Koricha Woreda

Sample Description: Bore Hole Water

Sample Location $S_{2:}$ Chitu Woreda

Sample Description: River Water

Sample Location $S_{3:}$ Wenchi Woreda

Sample Description: Lake Water

TABULATION

Sample No.	Temperature of Sample (°c)	Sulfate Test Result (mg/L)	
		Before	After
S_1	27	16	16
S_2	27	41	17
S_3	27	87	27

Result: -

The sulfate of the given sample S_1= 16 mg/L

The sulfate of the given sample S_2= 17 mg/L

The sulfate of the given sample S_3= 27 mg/L

Annex

Storage container with lid

Diffusion plate