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ASSESSMENT OF PERFORMANCE AND PRACTICABILITY OF BIO-SAND FILTER AT HOUSE HOLD LEVEL AND ASSESSMENT OF ITS NEED BY ANALYZING PERCEPTION OF PEOPLE FACING SAFE WATER SUPPLY

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ABSTRACT

The Bio-sand Filter developed by Dr. David Manz, has become one of the most widely-distributed devices for household water treatment in developing countries around the world. Over 1 billion people in the world lack access to safe water with a major feature of extreme Poverty. The purpose of this study was to investigate issues related with safe water supply and treatment behaviors in the study area and to analysis Bio-sand filter performance by changing the thickness of sand. Portable Bio-sand filtration unit for households had been constructed using locally available materials. The performance of these filters was also investigated in this study. In order to assess the performance of the slow sand filter that was constructed, samples were taken from both the influent and effluent and analyzed for turbidity, PH, microbial, electrical conductivity, head loss and flow rate and two filters of different sand thickness were compared and analyzed. From turbidity measurements of the influent and effluent of the BSF, The average Turbidity removal of filter1 is averaged to 50% and for filter2 it is 89%. The initial flow rate of filter1 is 13liter per minute per square meter and 9 liter per minute per square meter for filter2. The flow rates of the filter2 after ripening time ranged from about 4.3L per minute per square meter to 7.4 Lper minute per square meter and averaged 6L per minute per meter square. Average turbidity) than the filter with less sand thickness (of 22cm sand thickness) which removed only 50% of the total turbidity. Hydraulic conductivity (K) of filter1 is 5.62m/hr and 4.38m/hr for filter2. Generally the value of PH and electrical conductivity of both filters is decreasing with a detention time increment. The main factor of performance analysis and the design of the Bio-sand filter is sand thickness as it was observed and analyzed with different thickness of sand filter in two filters. The filter with greater sand thickness (28cm sand thickness) was found to be more effective in removing turbidity (89% of the total.

Key words:
Bio-sand filter, effluent, influent, microbial activities, performance, **ponded water**

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1. Introduction

1.1 Background

Slow sand filtration involves allowing water to slowly pass through a bed of sand or other porous material such as pumice, Rockwool, etc for treatment. Bio-sand filter for household use, commonly referred to as the Biosand Filter (BSF), was developed by Dr. David Manz at the University of Calgary, Canada, in the 1990's [3]. The Bio-sand Filter developed by Dr. David Manz, has become one of the most widely-distributed devices for household water treatment in developing countries around the world. Over 1 billion people in the world lack access to safe water with a major feature of extreme Poverty. Lack of access to clean water is locked in the heart of the poverty. Nearly all of these people live in developing countries, especially in rapidly expanding urban fringes, poor rural areas, and indigenous communitie [4]. Municipal water treatment systems are frequently impractical and often unaffordable in these settings especially in Ethiopia most of the inhabitants in rural areas drink untreated water from nearby springs, ponds from rain and streams, which are often contaminated due to nearby agricultural activity and waste disposal near the sources. As a result, there is an extremely high rate of parasitic infection (80-90% from medical studies conducted in 2007), leading to prolonged illness, low school attendance in children and reduced productivity in agriculture. Slow filtration of water is undoubtedly the most adequate technology for rural areas. The thesis contained in this document is a low-cost alternative that is technically adequate and easily managed by the community at house hold level.

1.2 Objectives

- **General Objective**

The general objective of this thesis is to analyze the performance and practicability of Bio-sand filter at house hold level and assess its need by analyzing perception of people facing safe water supply.

- **Specific Objectives**

- To assess attitudes and perceptions of peoples on the relationship between water qualities, the degree of water source protection and their attitude toward water treatment.
- To construct durable cost effective and portable bio-sand filter.
- To analyze the water quality of different sources.
- To determine suitability and effectiveness of bio-sand filter at removing turbidity and pathogens from water.

2. Research Methodology

2.1 Study Area Description

The study area is a rural area of Sidama zone, which is located in southern nation, nationality and People's Republic state which is found at 275km from Addis Ababa. The specific area of the site or Woreda for data source was identified by Sidama zone water and energy office based on the severity of the safe water supply problem in the area. Based on the safe water supply problem Boricha was selected. Boricha is one of the woredas in the Southern Nations, Nationalities and Peoples' Region of Ethiopia. Boricha is Part of the Sidama Zone located in the Great Rift Valley. It is located at about 25km from Hawassa city. It is bordered on the south by Loko Abaya, on the west by the Wolayita Zone, on the northwest by the Oromia Region, on the northeast by Awasa Zuria, on the east by Shebedino, and on the southeast by Dale. Boricha was separated from Shebedino woreda. Based on the 2007 Census conducted by the CSA, this Woreda has a total population of 250,260, of whom 125,524 are men and 124,736 women; 10,402 or 4.16% of its population are urban dwellers. The bio-sand filter performance analysis was carried out in Hawassa University specifically in water quality laboratory.

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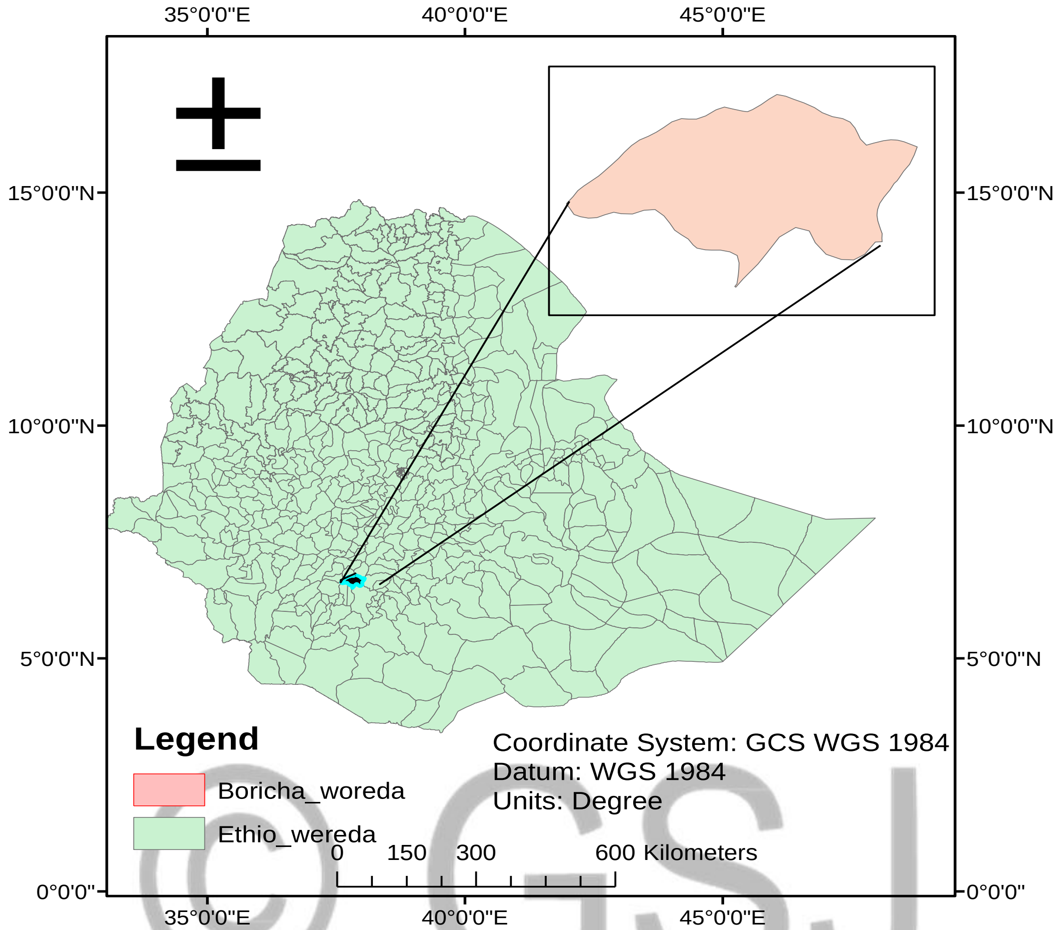

Figure 2.1 Location map of Birbir river watershed

2.2 Data collection

Mixed method data collection method was carried out during the survey period. The selection of the area was grouped into two major classes or regions of rural and urban areas. In the first stage the most seriously suffering Woreda from Sideman zone was identified. This Woreda is Boricha Woreda. Urban area of the Woreda and two kebeles of the Woreda were selected for survey study based on the severity of the problem. So that anja chafa Kebele and korangore Kebele were selected since they are suffering from safe water supply. As a second stage the simple random sampling were used to interview the respondents of the area. In the third stage, for the primary data collection the household heads (especially women who are responsible for water collection) were interviewed. The instruments of the research were structured and semi structured questionnaires and open-ended discussions were made with communities, water and energy office workers at zone and Woreda level and healthy office workers. In addition to that data on socio-economic, water utilization characteristics and household determinants of collecting water from improved water sources were gathered. Secondary data were collected about water source protection from the concerned experts, rural water office and water use committees. Besides that on site observation about the status of water ponds in each area were made.

2.2 Materials and Methods

To accomplish the research, Bio-sand filtration performance analysis and design improvement, an experimental Bio-sand filters had to

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be designed and constructed. So that these bio-sand filters were constructed from the combination of different materials. These are bio-sand filtration container (jerican), faucet and filter media materials (sand and gravel). To obtain the required effective diameter range of 0.15-0.35mm and uniformity coefficient (Cu) of sand and supporting gravel range from fine (2-5mm) to coarse (7-15mm) sieve analysis was made for both gravel and sand.

Figure **2.2 Bio-Sand Filter Containers (Jericans) Installation**

The size and thickness of the gravel and sand used for both containers is summarized in the table below.

Table 2.1 sizes and thickness of gravel and sand used for bio-sand filter

Material	Container 1		Container 2	
	Size (mm)	Thickness (cm)	Size (mm)	Thickness (cm)
Gravel	10	3	10	4
	5	4	5	2
	2	4	2	2
Sand	0.6	7	0.6	7
	0.3	8	0.3	9
	0.212	7	0.212	12

2.3 Water Sampling From the Source

Water samples were collected from different sources of water used by the communities in rural areas. A total of three water samples were collected for laboratory analysis from which the two samples were from rural areas of the Woreda (pond water) and the other from Hawassa lake water for the performance analysis of the bio-sand filter. The samples collected from unprotected ponds and Hawassa lake water sources were analyzed in water quality laboratory by coding them as shown below Table 3.2.

Table 2.2 water samples from different sources

Code	Water source type
UPA1	Unprotected pond water anja kebele
UPK2	Unprotected pond water korangore kebele
HLW4	Hawassa lake water

Based on the water quality of the samples investigated, the status of the existing water quality was compared with the standards of the world health organization (WHO, 2004).

Fig 2.3 Pond water and samples taken

2.4 Methods of Data Processing and Analysis

As stated earlier, the main objective of this study was to investigate the performance analysis and design improvement of the Bio-sand filter at house hold level. The effectiveness and the performance of the Bio-sand filter can be evaluated by various methods. The one used in this thesis include microbial tests, physicochemical test, flow rate, and physical observation. The effectiveness and performance analysis of these tests was evaluated by comparing with WHO standards guidelines. In addition to this identifying the number of factors that forced the community to use unimproved water sources, their willingness to use improved water sources and their perception on water sources quality were investigated. Questioners were also used to obtain information basically from women who took the greater responsibility of water collection and asked about the consumed water quality perceptions on color; taste and odor during data collection employed.

3. Results and Discussions

3.1 Water Quality Need Household Assessment

3.1.1 Socio-economic Characteristics of Respondents

The socioeconomic characteristics of respondents in boricha Woreda especially anja chafa and korangore Kebeles had been observed during the survey study. The two kebeles are located to North West at approximately 6km Anja chafa and 8km Korangore from boricha Woreda. Both areas are over green. Sugarcane, coffee, enset, chat and maize are dominant crops in the areas. Most of their houses are old grass house which seems to fall; Because of that they are not comfortable for rain water harvesting. The two kebeles have road accessibility with gravel roads. Small busses and motorcycles are used as transportation system.

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In addition to this carts are used for transportation of materials for market and water from far areas. In these areas people of different age, status and economic standards were interviewed.

Fig 3.1 Respondents interview in rural area of Boricha

Characteristics and status of the respondents are shown in Table 4.1. The table presents the respondents' distribution of household by sex (Table 4.2), occupation background (Table 4.1), age (Table 4.3) both in urban and rural areas. The age range in urban area was 45.5 percent are between 16 and 20, 38.5 percent between 21 and 25, 14 percent between 26 and 35 and 2 percent between 36 and 45 and 3 percent above 45 years old, 16 years of minimum and 55 years of maximum. The age range in rural area of 45.5 percent are between 16 and 20, 38.5 percent between 21 and 25, 14 percent between 26 and 35 and 2 percent between 36 and 45 and 3 percent above 45 years old, 16 years of minimum and 60 years of maximum.

Table: 3.1 Statistics of job of respondents

Job type	Frequency		Percentage (%)	
	Urban	Rural	Urban	Rural
Students	13	20	30	14
Farmers	-	85		62
Merchants and others	31	33	70	24
Total	44	138	100	100

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TABLE 3.2 DATA ON SEX OF RESPONDENTS

Sex	Frequency		Percentage (%)	
	Urban	Rural	Urban	Rural
Male	24	78	54	56
Female	20	60	46	44
Total	44	138	100	100

TABLE 3.3 DATA ON AGE OF RESPONDENTS

Age	Frequency		Percentage (%)	
	Urban	Rural	Urban	Rural
11-15	-	-	-	-
16-20	4	7	9	5
21-25	5	11	11	8
26-35	21	45	48	33
36-45	10	61	21	44
Over 45	5	14	11	10
Total	44	138	100	100

The results show a wide range of age proportion of the sampled respondents, which was good because it increased the likelihood of capturing and understanding community perception about water consumption behaviors and perceived quality of the source.

3.1.2 Households Existing Water Quality and Supply Problem

Boricha is one of the sidama zone Woreda which is most seriously suffering from the safe water supply problem. The study area is limited to this Woreda due to this problem. As we had been told by one of the team leader of water office in the woreda there are 12 rural Kebele and 2 urban Kebeles which have accesses to safe drinking water. There are different kinds of water supply sources available in those areas like the borehole of which 5 functional and 2 nonfunctional and HDW of which 17 functional and 16 nonfunctional and also shallow well of which have 1 functional and 4 nonfunctional. There are around 24 kebeles which have serious problem of safe drinking water supply like anjachafe and karangore which are surveyed during the study. In these Kebeles there is serious problem of safe water supply. The main source of water supply for those kebeles is pond water which is ponded from rain. There are 36 ponds in anjachafe Kebele which are aged two to three decades. These ponds are served by direct rainfall and overrunning flood which flows to the pond through the open channel constructed traditionally. No system was provided to screen out unwanted materials from the flood. The flood may carry the disposed wastes from households and also carry even human faces. The source of water is intended for both drinking and washing. They use different Mechanisms like filtration through a piece of cloth and tea filter to treat the water.

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Figure 3.2 Pond water for drinking and washing

The water borne disease like worm, scabies, and skin infection are dominant in the area. There is no surface water in the Kebele even in the Woreda and ground water is also not available near the surface because of its very deepness, it is very difficult to drill the well. But, many years ago some people were using it. But now it is dried and it is impossible to get water even if it is drilled to the depth they had been using it. As the respondents suggested, the decrease of rain fall from time to time is main reason to this problem. There is no separated pond water for both peoples and cattle's. In addition to the pond water from the rain they also uses the channels by constructing small earth dam to store water during rainy season. Some people were fetching the water from the open channels.

The ponds have very bad odour even at long distance and the color of the water seems flood water during the rain in addition to the algae and worms developed on the surface of the ponds. Turbidity test of this pond sample was done in the laboratory.

The NTU value of this water was found to be 206 NTU, which is very higher and higher when compared to WHO standard (<5 NTU). So it is not recommendable to use this pond water. However, it has PH value of 6.72 and this PH value lies in the range 6.5-8.5 which is recommendable PH value of potable water.

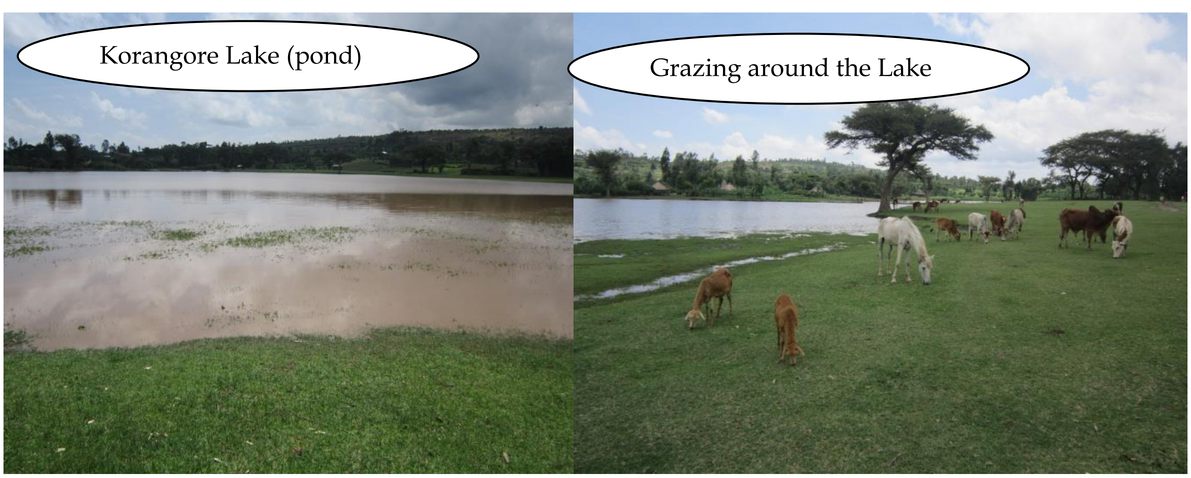

Figure 3.3 Pond water for drinking, washing and cattle's in Korangore kebele

They use simple filtration mechanisms to treat the pond water in home through a piece of cloth and tea filter. Water physical parameters like turbidity can also reduced if water is stayed in the pot for 1-3days so that soil particles and other solid materials settle down and almost the half of the pot (temporary storage) become the sediments. The people in this area are in a very serious problem as no pond water is available for 6 months and they are enforced to buy water from other area, which is transported from Hawassa area (deralitu, 10km from the area) by cart. The cost is high due to in accessibility of their area to road.

Figure 3.4 Water transportation from source to rural areas by a cart

In the very earlier they had been using water from well, but it is not available currently even if digged to more depth than before. They suggested the decrease in a rainfall as a reason. We have also observed that there are 4 bore holes drilled around the pond (lake). But they are filling the well back because of water unavailability up to 20m depth. NGO called goal Ethiopian had been digged this bore hole by human power. The bore hole has depth of 20m and those digged 4 bore holes around the pondage (lake), but water couldn’t find at depth of 20 m, so that they stopped drilling and decided to fill back the bore hole.

Figure 3.5 Borehole through goal Ethiopia and backfill

Generally there is a serious problem in the two Kebeles. Especially other people who come from other places like Hawassa, other city and their students from higher education training are in a very serious problem than people living in the area because they are suffering from water born diseases than people who adopted the water in the pond.

Because of that people from other area don’t like to work in the area (Woreda). Peoples living around the area have been adapted to some extent even though it does not give satisfaction when using it. There is no water around their school, so that students are obliged to stay for a long time through thirsty and the employer's works in the area do not use the water pond/supply from these areas. They use the water from shop or they fetch from other city. Professionals sometimes come from the governmental offices and promises to construct water projects for the area but till now they have not done it. They have encouraged people in the area to use Bio-sand filter and some people started to use it. But they are not using currently because of poor maintenance, no enough materials, no experience and no supervision from skilled professionals. Even they do not know the procedures and enough knowledge about how to use it.

3.2 Result and Discussion on Bio-Sand Filter Performance

3.2.1 Flow Rates measurement

Flow rate measurement was taken at both the initial stage and the operations stage (after ripening time). The initial flow rate of filter1 is 13 liter per minute per square meter and 9 liter per minute per square meter for filter2. The recommended initial flow rate (for the purpose of sand selection) is 10 ± 3L per square meter per minute (Ritenour, 1998) as cited by Tse-Luen Lee (2000). Initial flow rates of both filters lies in this recommendable range so it is ok. However, there is a reduction of flow rates through the time. The flow rates of the filter1after ripening time was taken for five days and ranged from about 5L per minute per square meter to 9Lper minute per square meter and averaged 7L per minute per meter square. The flow rates of the filter2 after ripening time ranged from about 4.3L per minute per square meter to 7.4L per minute per square meter and averaged 6L per minute per meter square. This flow rate results suggests that the BSF is capable of providing sufficient amounts of drinking water (3-7L per capita per day) to households of 3-10 average number of people if the filter runs for only one to three hours a day. Figure 3.7 describes the difference in flow rate the filter.

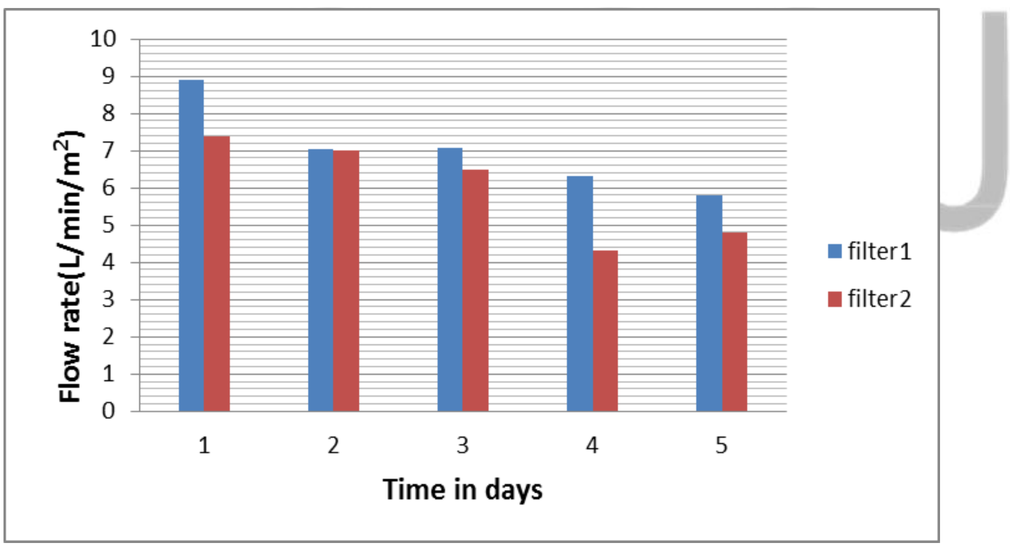

Figure 3.6 flow rate of the filters after ripening time

As it can be seen from the graph there is reduction in flow rate as the time proceeds for both filters. Rate of water flow through the sand filter is possibly the main variable that is determining filter effectiveness. Flow rate at day 2 for filter1 and day 4 for filter2 are lower than the next flow rate. This shouldn't happen so that there might be error in measurement or it can be problem of accuracy. Generally Flow rates of filter2 are lower than flow rate of filter1 this happened because sand thickness of filter2 is greater than sand thickness of filter1.

3.2.2 Turbidity Results

The turbidity of water coming out of a BSF after maturation is 3.15 NTU if averaged for the first filter over 5 days and 0.73 NTU if

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averaged for the second filter over 5 days. Both values are lower than 5 NTU, which is the WHO guideline for maximum allowable turbidity in drinking water. The average Turbidity removal of filter one is averaged to 50% and for filter two it is 89%. The detail difference between the filters over 5 days after maturation is described below by figure 4.8.

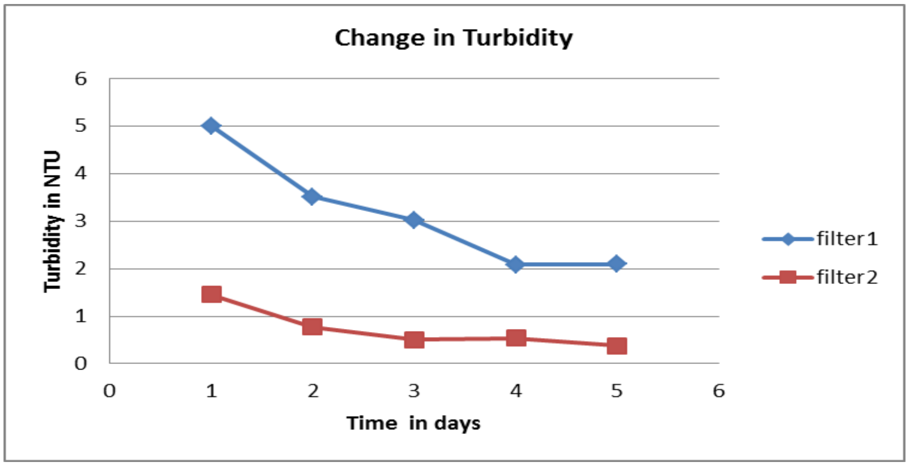

Figure 3.7 Turbidity of filters after maturation

As it can be seen from the figure there is great difference between the two filters. The ripening time and thickness of the two filters is different. Filter 1 has sand thickness of 22cm and filter2 has sand thickness of 26cm. The ripening time for filter1 is 15 days and filter2 is 11days. The ripening period for the Bio-sand filter is usually one to three weeks (Jellison et al., 2000). Since ripening time of both filters lies in this range it might not affect the effectiveness of the filter. It can be thought that the more ripening time the more effectiveness of filter but, the reverse happened in this case. Therefore, the difference in turbidity is occurred due to thickness of sand only. So we can conclude as, the more the thickness of sand the more effectiveness of the filter in removing turbidity.

3.2.4 Head loss and Hydraulic conductivity

In this study head losses of the two containers were obtained at different times to see the changes. The hydraulic conductivity was determined from each point. From Darcy's Law hydraulic conductivity (K) is calculated as:

$$K = Q\,L / A\,\Delta H$$

Where:

Q is the volumetric flow rate of water,

K is the hydraulic conductivity,

A is the Cross-sectional area that the water flows through, and

ΔH is the change in hydraulic head.

From this equation the average Hydraulic conductivity (K) of filter1 is 5.62m/hr and 4.38m/hr for filter2. This means the Hydraulic conductivity (K) of filter2 is less than Hydraulic conductivity (K) of filter1. This is happened due to difference in thickness of sand.

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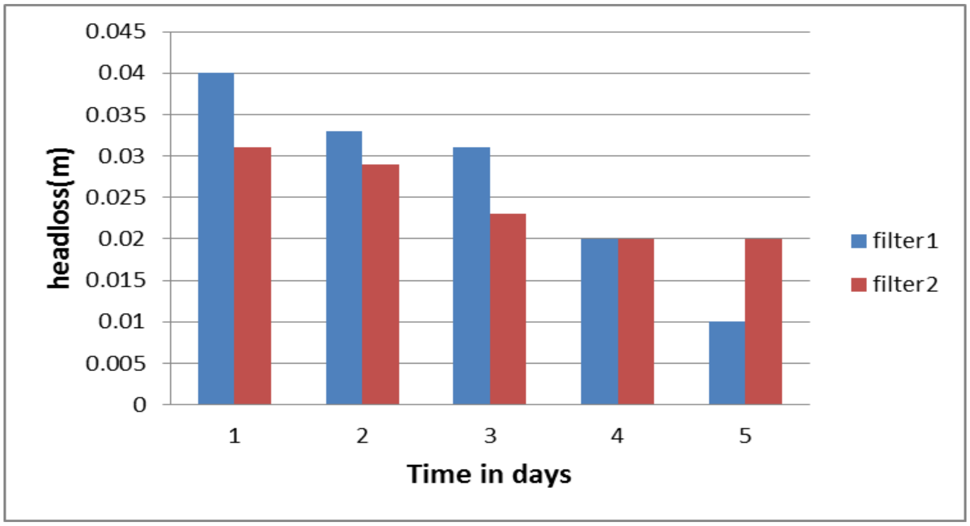

Figure 3.8 head loss with time progress

As it can be seen from the figure there is indirect relationship between head loss and time.

In both filters there is a decrement of head loss with increment of detention time. Generally the head loss of filter2 is lower than filter2; this is happened because the thickness of sand in filter2 is greater than thickness of sand in filter1.

3.2.4 Electrical Conductivity and PH Results

The average PH value of the influent water added is 7.05. This value lies in the recommended PH range of 6.5-8.5 which is acceptable as potable water. However, the PH value of effluent water is generally higher than PH value of influent water which has a range of 7.1-7.48 as obtained in five days. The higher PH of effluent water than influent water suggests that there are primarily dissolved minerals from sand layer. The average electrical conductivity of influent water added is 1240 µmhos/cm. Electrical conductivity of effluent water is generally higher than electrical conductivity of influent water. The electrical conductivity of filter1 is ranged from 1267-1420 µmhos/cm and electrical conductivity of filter2 is ranged from 1304-1407µmhos/cm. The values of electrical conductivity of effluent water in both filters got lower and lower than electrical conductivity value of previous effluent water. The electrical conductivity of filter1 is lower than electrical conductivity of filter2. The values of PH and electrical conductivity of both filters in five days are as shown in figures 3.10.

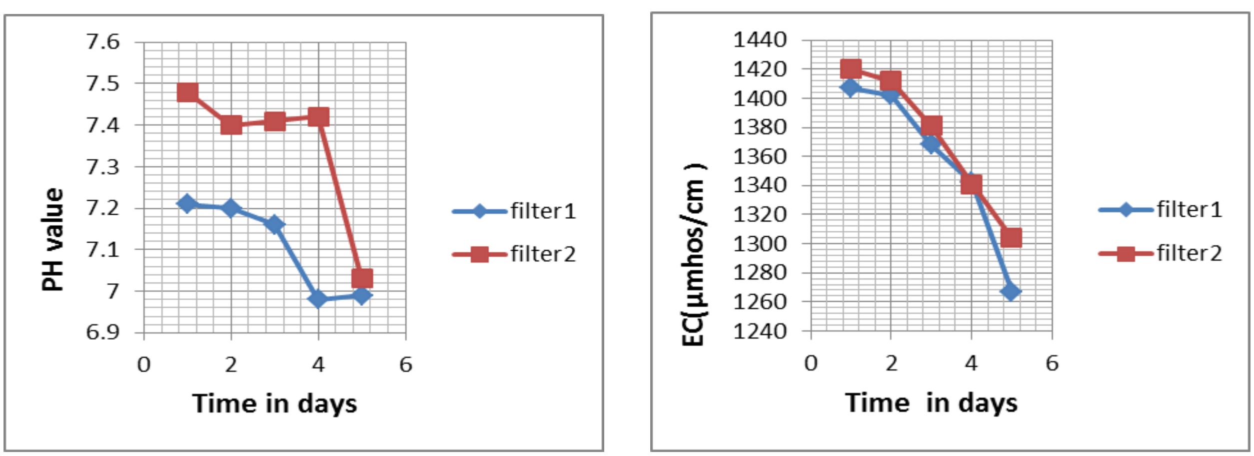

Figure 3.9 PH value and electrical conductivity with time progress

As it can be seen from the figure there is indirect relationship between PH value of effluent water and time. In both filters there is a decrement of PH values with increment of storage time. The value of PH and electrical conductivity of both filters is decreasing with a detention time increment. This may indicate that metals are being dissolved and there is leaching away from these metals ions like (Na+, Ca++, Mg++, K+). The PH value and electrical conductivity of filter2 is higher than filter1; this is happened because the thickness of sand in filter2 is greater than thickness of sand in filter1. This suggests that the source of dissolved minerals is a sand layer. Generally electrical Conductivity and PH change with storage time. However, this is not true for day 5 in filter1 and day 2 in filter2. This might be happened due to temperature changes in addition to storage time as both EC and PH are highly affected by storage time and temperature.

4. Conclusions

The main source of water supply for the study area (anjachafa and korangore) kebeles is pond water which is stored from rainfall. These ponds are served by direct rainfall and overrunning flood which flows to the pond through the open channel constructed traditionally. There is no enough and consistence and sustainable water sources for households and also much of the water sources are contaminated and lead to water borne disease and there are different animals like cattle and sheep which use the same source of water that of households. The average Turbidity removal of filter one is averaged to 50% and for filter two it is 89%. The initial flow rate of filter1 is 13liter per minute per square meter and 9 liter per minute per square meter for filter2. Initial flow rates of both filters lies in this recommendable range so it is accepted. The flow rates of the filter2 after ripening time ranged from about 4.3L per minute per square meter to 7.4Lper minute per square meter and averaged 6L per minute per meter square. This flow rate results suggests that the BSF is capable of providing sufficient amounts of drinking water for households. Average Hydraulic conductivity (K) of filter1 is 5.62m/hr and 4.38m/hr for filter2. This means the Hydraulic conductivity (K) of filter2 is less than Hydraulic conductivity (K) of filter1. This is happened due to difference in thickness of sand. Generally the value of PH and electrical conductivity of both filters is decreasing with a detention time increment. This may indicate that metals are being dissolved and there is leaching away of these metals ions. The PH value and electrical conductivity of filter2 is higher than filter1; this is happened because the thickness of sand in filter2 is greater than thickness of sand in filter1. This suggests that the source of dissolved minerals is a sand layer. The main factor of performance analysis and the design of the Bio-sand filter is sand thickness as it was observed and analyzed with different thickness of sand filter in two filters. The filter with greater sand thickness (28cm sand thickness) was found to be more effective in removing turbidity (89% of the total turbidity) than the filter with less sand thickness (of 22cm sand thickness) which removed only 50% of the total turbidity.

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