"KANCHAN™ ARSENIC FILTER: REMOVAL OF BACTERIA (TOTAL COLIFORM) OF Gem 505 MODEL" 4 WEEKS DAILY STUDY

A Thesis
Submitted in partial fulfillment for the requirements for Bachelor Degree in Environmental Science (Honor's Degree) to the Department of Biological Sciences and Environmental Science
School of Science, Kathmandu University

By

Dipina Sharma

KATHMANDU UNIVERSITY

July 2005

Declaration by student

I, Dipina Sharma, hereby declare that this thesis entitled **"*Kanchan*™ Arsenic Filter: Removal of Bacteria (Total Coliform) of Gem 505 model"** submitted in partial fulfillment of the requirements for the Bachelors degree in Environment Science (Honor's degree) at Kathmandu University during the academic year 2005, includes the work done originally by me under the supervision of my supervisors. The thesis has not been published or submitted elsewhere for the requirement of a degree programme. Any literature, data or work done by others and cited within this thesis has been given due acknowledgment and listed in the reference section

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Declaration by the Supervisors

We, Dr. Sanjay Nath Khanal, Associate Professor, Kathmandu University, Sangita Shakya, Assistant Professor, Kathmandu University and Dr. Roshan Raj Shrestha, Chief Technical Advisor, UN Habitat (Ex-Executive Chairman, ENPHO) hereby declare that the work presented herein is genuine work done originally by Dipina Sharma and has not been published or submitted elsewhere for the requirement of a degree programme. Any literature, data, or works done by others and cited within this thesis has been given due acknowledgement and listed in the reference section.

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Abstract

Arsenic contamination in ground water of Terai region of Nepal is a new challenge of the nation to meet the safe drinking water to its population. In addition to arsenic, microbial contamination is another factor which is another serious contamination issue. Those who consume this contaminated water may suffer from various water borne diseases. In order to combat these problems, *Kanchan*^{TM} Arsenic Filter was developed as a modified version of Biosand filter. *Kanchan*^{TM} Arsenic Filter is considered to be an appropriate technology for the removal of arsenic along with pathogens; iron and turbidity from the ground water drinking sources.

This study was conducted for a month (March 2005, pre-moonsoon season) in the village of Kasiya of Nawalparasi District in order to investigate the biological processes within the *Kanchan*^{TM} Arsenic Filter responsible for removing Total Coliform. Five filters were setup. Membrane filter test were performed to evaluate the filter performance in the removal of Total Coliform and source water quality. Parameters such as turbidity measurement and flow rate were also recorded throughout the experimental period.

Kanchan^{TM} Arsenic filters were found to be effective in removing Total Coliform and Turbidity. Four of five filters were able to remove over 95% Total Coliforms, all filters produced water of less than 5 NTU turbidity, and all filters can produce adequate volume of water for the households. Biofilm appeared to have ripened in as little as nine days. The users liked the high flow rate simple operation, minimal cleaning as well as the clear and odour free effluent water.

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List of Abbreviation

ABF	Arsenic Biosand Filter
BSF	Biosand Filter
CFU	Colony Forming Unit
ENPHO	Environment and Public Health Organization
KAF	*Kanchan*™ Arsenic Filter
L	Liter
LRV	Log Reduction Value
MIT	Massachusetts Institute of Technology
NTU	Nephlometric Turbidity Unit
P/A	Presence/ Absence
ppb	Parts per billion
ppm	Parts per million
UNEP	United Nation Environment Program
UNICEF	United Nation Children's Fund
WHO	World Health Organization

1. Introduction

1.1 Water resource, water supply and water quality of Nepal

Access to safe water is a basic human right that has not been available to a large proportion of world's population. Only 0.7% of the world's water supply is available for consumption and, unfortunately, it is disproportionately distributed (UNEP, 1991). Over one half of the people living in developing countries suffer from diseases related to unsafe water supply and sanitation (WHO, 1996). More than 2.6 billion people – forty per cent of the world's population lack basic sanitation facilities, and over one billion people still use unsafe drinking water sources. The majority of these people live in Asia and Africa, where less than one-half of all Asians have access to improved sanitation and two out of five Africans lack improved water supply. About 400 million children in the world lack even the bare minimum of safe water they need to live, while 40 children die each day in Nepal from diarrhea and other water borne diseases (UNICEF, 2002).

These water quality problems that plague much of the developing world also plague Nepal. The microbial contamination of drinking water or water- related illness is most dire in Nepal. Although Nepal is rich in freshwater resources, the failure to achieve safe water and sanitation is one of the biggest tragedy of the nation. Nepal was ranked 78th in water quality in the world (UNICEF, 2003). Although the government has provided "*basic*" water to over 80% of the people as per the five-year plan of Nepal, only 34% of the total population has access to "*safe"* drinking water. Pathogens, such as viruses, bacteria, protozoa and helminthes found in natural water are responsible for diseases such as diarrhoea, intestinal worms, trachoma, schistosomiasis, cholera, amebiasis, giardiasis, stunting and many more. Although the governmental and non-governmental organizations in Nepal, including bilateral and international donors, have been involved in the effort to provide safe water supply, a major effort is still required. In order to meet the internationally agreed targets for water and sanitation improvement, the decade 2005- 2015 is officially declared as "Water for Life" with a hope to bring remarkable gains.

Unfortunately, Nepal is the seventh poorest nation in the world with an average annual income of US $ 240 (UNICEF, 2003) and this poverty may also be the cause of some of the worst national health statistics in the world:

- 25% of infant deaths are due to diarrhea (WHO, 1998).
- 48% of the population is stunted due to an inability during infancy and childhood to retain essential nutrients during diarrheic episodes (WHO, 1998).
- Estimates of infant mortality m/f are 81 and 87 per 1000 (WHO, 2002).
- Number of children that die before the age of five annually is 67,000 (UNICEF, 2003).
- Life expectancy is 60 years (WHO, 2003).

Ground water contamination with Arsenic, a high toxin poison is another crosscutting issue that is affecting the access to safe drinking water in the Terai belt of Nepal. An ongoing study of UNICEF estimates that 3% of the total population in the Terai region, home to 48.4% of the total population is drinking water with higher the Nepali interim guideline on Arsenic. Arsenic contaminated water has no distinct taste and smell. It is not visible in water and even highly contaminated water may be clear and colorless. The only way to detect about the presence of arsenic in water is by testing it. The districts of Nawalparasi, Rautahaut, Bara, Parsa, Siraha, Saptari, Kapil bastu, Rupandehi, Bardiya and Kailali are found to be highly affected by Arsenic. Sometimes the Arsenic level is even found to be >0.50mg/L which is 50 times higher than the WHO standard of 0.01mg/L (ENPHO Magazine, 2004). The tenth five-year plan of Nepal has formulated a national steering committee on arsenic to address the problems and potential dangers form Arsenic. Mitigation measures are already underway in the Terai but in small scale. The various ongoing schemes such as sharing safe tube wells, Arsenic filters and using improved dug wells are already making impact in providing safe or potable water to the affected people.

1.2 Drinking Water Sources of Terai

Ground water accessed via tube wells is the major source of water in the Terai Region of Nepal. The tube-wells range from private, one-family wells to village wells, which are shared by several families and anyone who passes by. Arsenic and microbes may be found in such tube well water. Typically, deeper tube wells have less microbial contamination when they are properly installed and maintained. A proper tube well should have both a cement cover with a tight seal around the well base and a drainage ditch flowing away from the well. Well priming should also be performed using water known to be pathogen free, and not the water from nearby ponds, as is commonly used in the Terai. Even if water does not become contaminated at the source, it may be contaminated sometime during the chain of events before it is consumed. Dirty hands, improper storage, and unsanitary collection methods can all result in the microbial contamination of drinking water.

1.3 Safe Household Drinking Water via Kanchan^{TM} Arsenic Filter (KAF)

If real reduction in waterborne disease is the desired result, many factors must be considered before implementation of point of use water treatment technologies. Pathogens contaminating the water supplies must be identified, user demand accessed and an appropriate technology selected. Considering all these factors the KAF seems to be a good solution. Efficiency tests show that this filter removes more than 95% of arsenic and 99% of iron. This system does not deteriorate the microbial quality of water, which is normally a major disadvantage of many other household level arsenic removal filters so far practiced (Shrestha, Ngai, and Dangol, 2004). The combination of physical- chemical and biological processes in the KAF can give up to 100% efficiency on bacterial removal. However, the bacterial removal efficiency may be low (only 50-60%) during the period immediately after filter installation. It normally takes a period of one to three weeks for a biological layer to develop to maturity in a new filter. The removal efficiency increases with the growth of biological layer. The research will be focused on the efficiency of the KAF for the removal of Total Coliform.

1.4 Research Objective

- To better understand the biological processes of the KAF.
- To determine the factors affecting the biological removal efficiency of the KAF in actual field setting.
- To serve as a database for refining the KAF that can achieve 100% efficiency in pathogen removal with minimal start- up time.

1.5 Limitation of the Study

- This experiment was conducted during the pre-monsoon season. Microbial count in influent may change during the monsoon and post- monsoon season. As a result, microbial removal efficiency of the filter may be affected as well.
- The turbidity of influent may increase during monsoon season with larger amount of fine silts. As such, the turbidity removal efficiency of the filter may also vary during pre- monsoon and post- monsoon season.
- Higher the content of fine silts in influent, more quickly the filter will clog. Clogging at the top of the filter would result in decreased flow rate. Hence, flow rate of the filter may also be affected during monsoon period.
- This experiment used raw water from Kasiya village of Nawalparasi district only. The results may not be applicable in other districts on Nepal where the water quality and geological conditions may differ.

2. Literature Review

2.1 An Introduction to Water Borne Pathogens

Infectious diseases caused by pathogenic bacteria, viruses and protozoa or parasites are the most common and wide spread health risk associated with drinking water (WHO, 1996). These pathogenic organisms such as bacteria, viruses, protozoa differ widely in size classification, structure and composition. They are responsible for many thousands of diseases and deaths each year, especially in tropical regions with poor sanitation.

All water borne human pathogens are not of equal public significance. Some of them present a serious risk of disease whenever they are consumed in drinking water and are given high priority for health significance. Examples include strain of *Escherichia coli, Salmonella, Shigella, and Vibrio Cholera.* On the other hand, some organisms may be "opportunistic". These organisms cause infection mainly among people with impaired natural defense mechanisms. These people include the very old, the very young, immuno compromise people and the patients in hospitals. Examples of these organisms include *Pseudomonas, Klebsiella* and *Legionella.*

2.2 Main Classes of Pathogens

The majority of waterborne pathogens can be categorized as bacteria, viruses, and protozoa.

2.2.1 Bacteria (Prokaryotic)

Bacteria are singled- celled prokaryotes with the size ranging from 0.3 to 100 micrometers in length. Bacteria *Salmonella typhi* and *Vibrio cholera* cause typhoid fever and cholera respectively. Common sources of bacteria are human feces. *Escherichia coli*, which is commonly used to indicate fecal contamination, causes

bacterial infections of the intestine of which the major symptom is diarrhea (Atlas and Bartha, 2000).

2.2.2 Virus (Noncellular)

Viruses are different from bacteria because viruses need a host to multiply. Also, they are much smaller in size (0.02-0.3) micrometers, have low infection dose (possibly only one organism), can result in disease like polio, hepatitis A etc. Like bacteria, viruses are associated with fecal matter and present health risk to an infected person (Atlas, 1995).

2.2.3 Protozoan Parasite (Eukaryotic)

Protozoa are unicellular eukaryotic microorganism. Protozoa usually obtain their food by ingesting other organisms or organic particles. Large number of protozoa can infect human by staying as parasites in the intestines of humans. The most common protozoal diseases are diarrhea and dysentery. *Entamoeba hystolytica, Giardia intestinal, and Cryptosporidium parvum* is all protozoan microorganism that result in Amebiasis, Giardiasis and Cryptosporidiosis, respectively. Protozoan cysts such as *Giardia intestinalis* and *Cryptosporidium patvum* cysts are relatively larger being 7-12μm and 3-10μm respectively. Cysts of such protozoans are easily filtered through media but are resistant to disinfection. Any unfiltered water supply is, therefore, suspicious (Atlas, 1995).

Table 2.1: Waterborne pathogens and their significance in water supplies

Pathogens	Health Significance	Persistence in Water Supplies[a]	Resistance to Chlorine[b]	Relative Infectivity[c]	Important Animal Reservoir
Bacteria					
Campylobacter jejuli, C.coli	High	Moderate	Low	Moderate	Yes
Pathogenic[d] Escherichia coli	High	Moderate	Low	Low	Yes
Salmonella typhi	High	Moderate	Low	Low	No
Other salmonellae	High	May multiply	Low	Low	Yes
Shigella spp.	High	Short	Low	Moderate	No
Vibrio cholera	High	Short	Low	High	No
Yersinia enterocolitica	High	Long	Low	Low	Yes
Pseudomonas aeruginosa[e]	Moderate	May multiply	Moderate	Low	No
Viruses					
Adenoviruses	High	Long	Moderate	High	No
Enteroviruses	High	Long	Moderate	High	No
Hepatitis A	High	Long	Moderate	High	No
Hepatitis E	High	Long	Moderate	High	Potentially
Noroviruses and Sapooviruses	High	Long	Moderate	High	Potentially
Rotavirus	High	Long	Moderate	High	No
Protozoa					
Giardia intestinalis	High	Moderate	High	High	Yes
Cryptosporidium parvum	High	Long	High	High	Yes

Source: WHO, 2004.
Note:

[a] Detection period for infective stage in water at 20 ° C: short, up to 1 week; moderate, 1 week to 1 month; long, over 1month
[b] When the initiative stage is freely suspended in water treated at conventional doses and contact times. Resistance moderate, agent may be completely destroyed.
[c] From experimental with human volunteers or from epidemiological evidence.
[d] Includes enteropathogenic, enterotoxigenic and enteroinvasive.
[e] Main route of infection is by skin contact, but can infect immunosuppressed or cancer patients orally.

2.3 Indicator Organisms of Drinking Water

The probability that a person will be infected by a pathogen cannot be deduced from the pathogen concentration alone. This is because different humans respond differently to the pathogens. Safe drinking water should be that with no pathogens.

Bacterial contamination cannot be detected by sight, smell or taste. There are two approaches for the determination of the pathogens in water. The first one is the direct detection of the pathogen itself. While this gives much more accurate information about the presence of specific pathogen while determining the water quality, there are several problems associated with it. First, it is impractical to test for each of the wide variety of pathogens present. Secondly, the methods used for the direct determination of these pathogens are relatively expensive, time consuming and often difficult (WHO, 1996). Instead, water monitoring for microbial quality is primarily based on the second approach that is to test for "indicator organism". The concept of indicator organism was introduced in 1892 and is the basis for microbial quality standards in water today (Hach, 2000). The indicator organism should fulfill the following mentioned criteria (Maier, Pepper and Gerba, 2000).

- The organism should be useful for all types of water.
- The organism should be present whenever enteric pathogens are present.
- The organism should have a reasonably longer survival time than the hardiest enteric pathogen.
- The testing method should be easy to perform.
- The density of the indicator organism should have some direct relationship to the degree of fecal pollution.
- The organism should be a member of the intestinal microflora of warm-blooded animals.

Another reason for using simple indicator tests is that pollution is often intermittent and/or undetectable. It is often better to monitor drinking water frequently by means of simple test rather than to monitor infrequently using a longer and more complicated direct pathogen detection procedure (Low, 2002).

2.4 Coliform Organism (Total Coliform) as an Indicator Organism

"Coliform Organism" is gram negative, aerobic or facultative rod shaped non-spore forming bacteria. They are capable of growing in presence of bile salts and able to ferment lactose at an optimum 35 °C, with the production of acid, gas and aldehyde with in 24 to 48 hours. In 1914 the U.S. Public Health Service adopted the coliform group as an indicator of fecal contamination of drinking water (Gerba, 2000). The approach is based on the assumption that there is quantifiable relationship between the concentration of coliform indicators and the potential health risks involved. The main reason for choosing Total Coliform as an indicator organism is because it is easy to detect and enumerate in water and are representative enough for determining faecal contamination of drinking water. By monitoring coliform bacteria, the increase or decrease of many pathogenic bacteria can be estimated. However, for developing countries in tropical climates, WHO states that,

> *Total Coliform bacteria are not acceptable indicators of the sanitary quality of rural water supplies; particularly in tropical areas…. It is recognized that, in the great majority of rural water supplies in developing countries, fecal contamination is widespread (WHO, 1996).*

Therefore, the use of Total Coliform as a microbiological indicator of faecal contamination or pathogenic contamination in drinking is not appropriate. Recognizing this limitation of only using the Total Coliform indicator, WHO adopted the use of Thermotolerant Coliform and *E. coli* as additional indicators for fecal contamination or pathogenic contamination in drinking water (Low, 2002). However, Total Coliform is usually enumerated to assess the performance of water treatment system. Since Thermotolerant Coliforms and *E. coli* are subclass of Total Coliform, it

is assumed that when there is 100% removal of broader class Total Coliform, Thermotolerant Coliform and *E. coli* are also removed.

The Total Coliform group includes, *Escherichia, Citrobacter, Enterobacter, Klebsiella* species. The Total Coliform bacteria can also be found naturally in soil and on vegetation. The incubation period for Total Coliform is 24 hours at 35°C. The WHO guidelines for Total Coliform in drinking water are set at zero CFU/ 100ml and zero for *E. coli.*

2.5 Bacteriological Quality Improvement in the KAF

The KAF is a solution to encourage an incremental improvement in water quality at the most affordable cost to the local communities of Terai region. This will serve as the first step towards providing safe drinking water supplies especially in the rural areas that have greater difficulty in achieving these water standards.

2.5.1 Brief history of Slow Sand Filtration Theory

Slow sand filters were developed in the 1820s in Europe as a water treatment technology, and successfully established by the end of the 19th century. In the 1980s, slow sand filters were designed for household-scale use—called the BioSand Filter (BSF). The BSF was developed by Dr. David Manz of the University of Calgary, Canada. This filter was previously introduced in Terai region for the removal of iron and bacteriological contamination. Dr Manz began his design process with the objective of creating an appropriate, easily transferable treatment technology for developing countries. Never losing sight of this objective, Dr. Manz has adapted the Biosand water filter to meet developing countries need with emphasis on filter construction and maintenance by local people with available materials (Lukacs, 2001).

In this system, water is simply poured into the top of the filter. As the water flows through the filter cake (biological layer) that forms the sand water interface and the

sand media, microbial contamination is removed. The primary construction materials are sand and concrete, which can be found in most rural village. Much like its continuous counterpart, BSF requires no chemical additives.

2.5.2 Evolution of KAF

By combining the encouraging results for the removal of pathogens, turbidity and iron through the BSF and the principle arsenic removal through adsorption to ferric hydroxide (as in Three Kolshi System) the researches from MIT and ENPHO have modified the BSF for the removal of arsenic together with pathogens, turbidity and iron (Shrestha; Ngai and Dangol, 2004). The KAF is a modified version of the BSF. Four different configuration of KAF are in operation at present that include concrete square, concrete round, plastic Hilltake and plastic Gem505 model. With each new model, improvements are made. Each new model is built upon the collective creativity of previous model, so that over time, improvements are being taking place in terms of economy, comfort and portability. Here the creativity lies in the refinement, the step-by-step improvement, rather than in something completely new.

2.6 Design of KAF, Gem 505 model

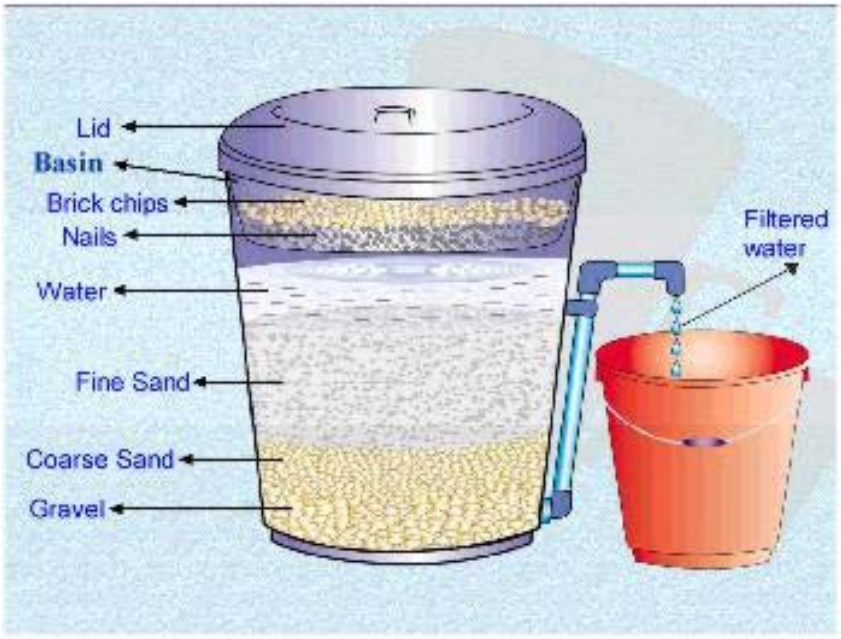


*Fig 2.1: **C**ross section of Kanchan™ Arsenic Filter, Gem 505 model (Source: ENPHO)*

KAF comprises two removal units: **Arsenic Removal Unit** and **Pathogen Removal Unit**. The arsenic removal unit is consisted of plastic basin with iron nails and some brick chips in it. The pathogen removal unit is consisted of water, sand and gravel layers.

2.7 Arsenic Removal Unit

The non-galvanized iron nails of the filter rust very quickly as they are exposed to water and air. When arsenic- contaminated water is poured in the filter, the arsenic is rapidly absorbed onto the surface of the ferric hydroxide particle or iron rust. The arsenic absorbed ferric hydroxide is flushed down and is trapped down on top of the fine sand layer, and as a result, arsenic is effectively removed (Ngai and Walewijk, 2003).

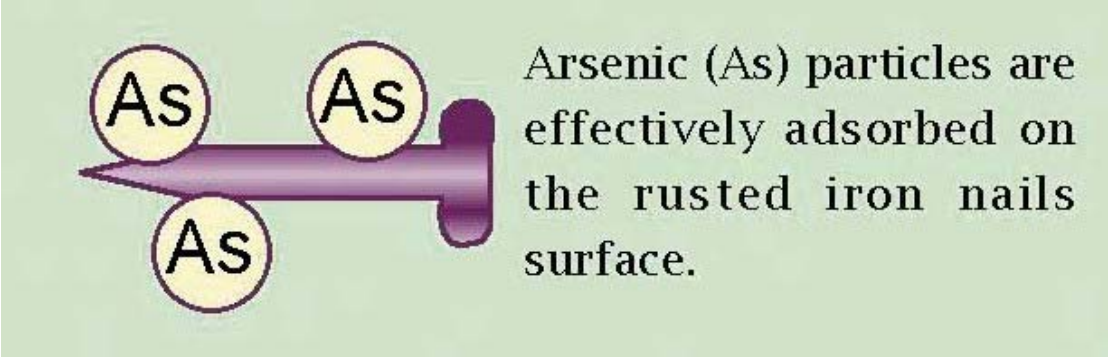


Fig 2.2: Illustration of Arsenic Removal Mechanism.(Source: ENPHO)

2.8 Pathogen Removal Unit

It is believed that there are mainly 4 different mechanisms for pathogens removal, namely physical straining, inter- particle attraction, predation and natural die- off.

2.8.1 Physical Straining

Physical straining is an important process responsible for the pathogen removal in KAF. Physical straining refers to the trapping of foreign particles on top of the filter

bed because the particles are too large to pass through the bed. A tightly packed bed of spherical grains could capture particles about 5% of the grain diameter (Ngai and Walewijk, 2003). As the foreign particles are captured at the surface, the surface pore opening become smaller and physical straining is enhanced, allowing the capture of much smaller particles as the filter cake develops (Lee, 2000). Filter cake is defined as the deposition of foreign particles such as, dust, dirt, organic substances and iron particles on fine sand layer.

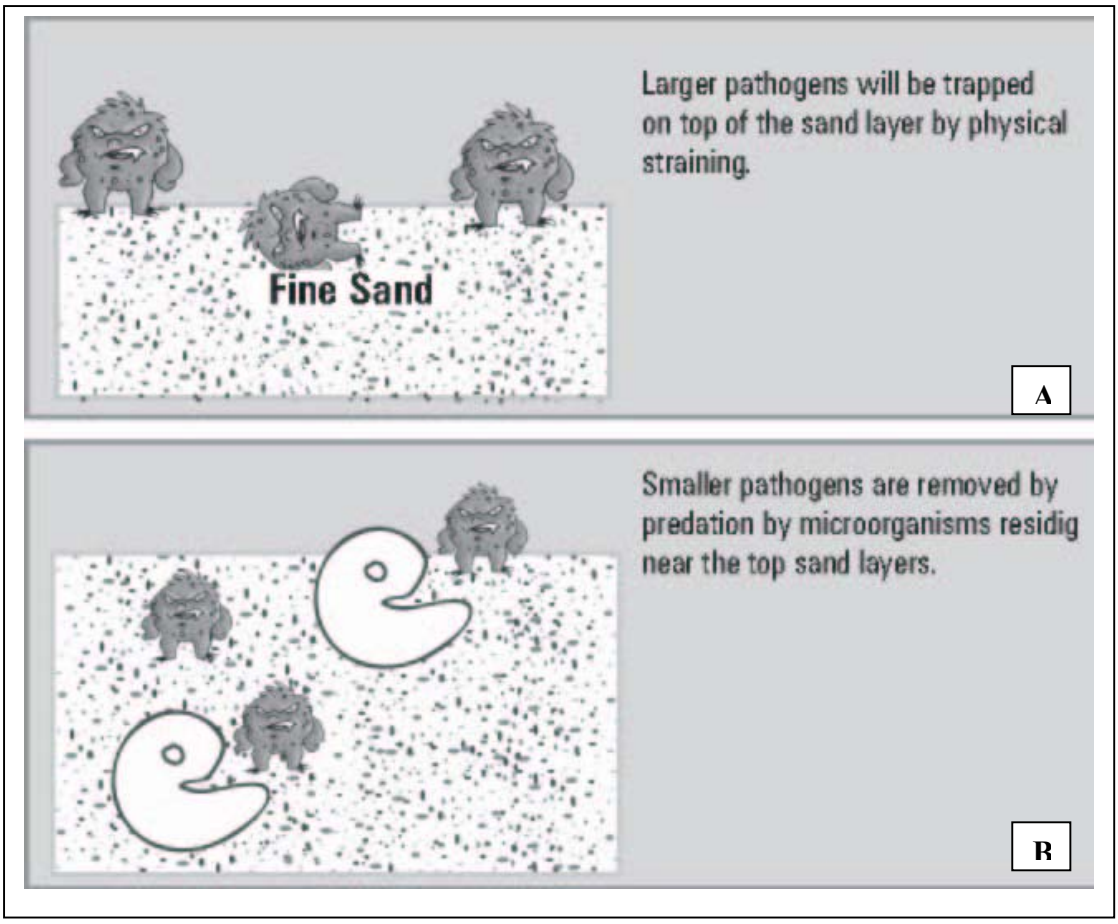
2.8.2 Inter-particle Attraction

Inter-particle attraction refers to the process with which the foreign particles are absorbed to the filter medium i.e. sand (Ngai and Walewijk, 2003). Prior to attachment, the particles are transported along flow streamlines unless they are captured by interception or transported across the streamlines causing them to reach a grain surface. If the conditions at the grain surface provide favorable particle-to-grain interaction, attachment will occur (Lee, 2000).

2.8.3 Predation

Over time, the filter cake is developed on the solid surface of fine sand as a result of physical straining process and inters- particle attraction. Dissolved organic carbon, dissolved oxygen, and nutrients present in influent support elevated biological population within this filter cake and at the sand- water interface. This biological population consists of various organisms such as algae, bacteria, protozoa and small invertebrates. This diverse population is known as biofilm.

When microbially contaminated water is poured into KAF, predator organisms that reside in the biofilm layer will consume the incoming pathogens. Recent studies and experiment conclude that this process can be a significant cause of bacterial removal in slow sand filters (Ngai and Walewijk, 2003).



Physical staining is illustrated in (A). Bacteria are too large to pass through the sand. Biological removal by predation is illustrated in (B). The microorganisms living in the biofilm consume incoming bacteria.

Fig 2.3: A Simplified Illustration of the Pathogen Removal Mechanisms. Source: KAF booklet, ENPHO

2.8.4 Natural die- off

As the filter cake consists of diverse biological population, most organisms will die in a relatively hostile environment due to increased competition.

2.9 Filter ripening

When a KAF is newly installed, or when the biofilm layer is damaged, time is needed for the biofilm to grow to maturity. This is called the ripening period. During this

ripening period the bacterial removal efficiency of the filter is less because only physical straining mechanism and inter- particle attraction are at work.

2.10 Iron Removal Mechanism

Soluble iron (II) in influent water is oxidized to iron (III) as soon as the water is exposed to oxygen in air. The oxidation process of Fe (II) to Fe (III) is usually pretty fast. Fe (III), which is available as brown precipitate is trapped on top layer of fine sand of the filter.

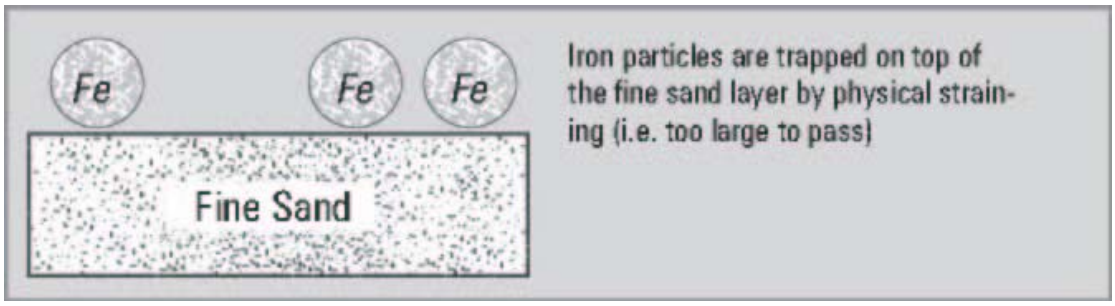


Fig 2.4: A simplified Illustration of Iron Removal Mechanism. Source: KAF booklet, ENPHO

2.11 Filter Cleaning Procedure

Over the long period of use, particles and dirt will be collected on the top of the fine sand layer. These filtered materials tend to clog the filter and the filtration rate will be reduced. If the filtration rate is too low that the filter cannot produce sufficient water, then the filter should be cleaned according to the procedure. Depending on the quality of the influent water (e.g. turbidity, iron concentration, usage, and seasons (e.g. monsoon), the filter may need to be cleaned once every month to once every 6 months (ENPHO, 2005).

3. Materials and Methods

This Section 3 involves the methodology for the field survey or well selection process and laboratory tests that were performed during research period to know the effectiveness and performance of KAF, Gem505 model. The effectiveness and the performance of KAF could be evaluated in number of ways and parameters such as microbial test or Total Coliform test; turbidity and flow rate were monitored during the study period.

3.1 Description of Study Area

Study was conducted in Kasiya village, Ward number- 12, Ramgram municipality of Nawalparasi District. Kasiya lies towards east of Parasi Bazaar in Nawalparasi district (Fig 3.1). The people of Kasiya mainly depend on tube well water for their drinking purpose. KAFs were provided to a few households in the summer of 2004 as part of a village demonstration program.

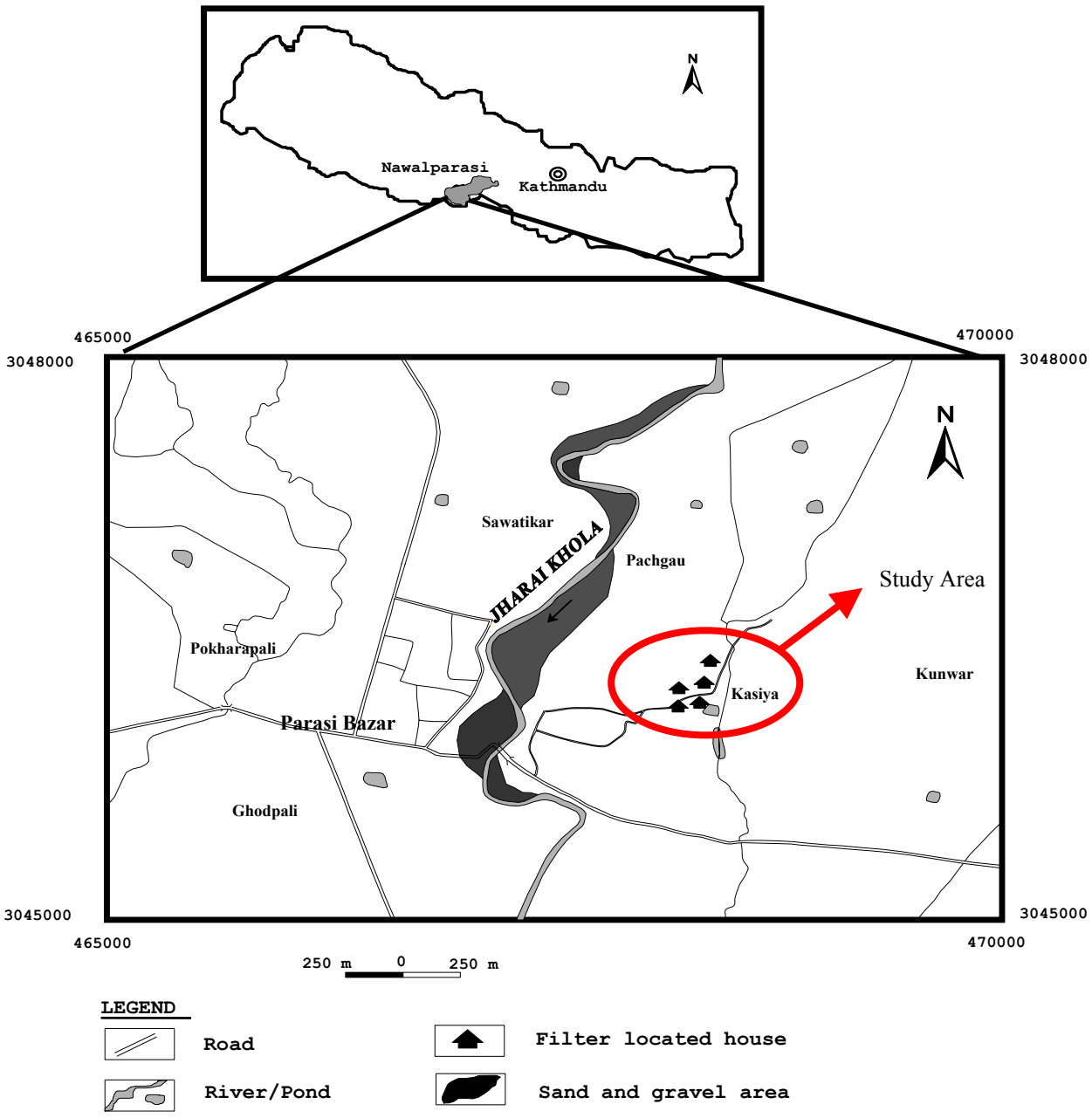


Fig 3.1: Location of Study Area

3.2 Reconnaissance Survey for Tube- Well Selection

3.2.1 Procedure and Criteria

1. The main criterion for the selection of Tube well was the level of Total Coliform in influent water. In Kasiya, four tube wells were selected as follows:

Table 3.1: Kasiya Tube well test Results

Filter Number	***User name***	***Total Coliform in Tube well water (CFU/100 mL)***	***Use Piyush in Installation***	***Remarks***
1.	**Ganesh Harijan**	20	Yes	TW 1
2.	**Swami Nath Yadav**	113	Yes	TW 2
3.	**Ghama Pr. Chaudhari**	113	Yes	TW 2
4.	**Madav Lal Shrestha**	138	Yes	TW 3
5.	**Sudarshan Chaudhari**	0	Yes	TW 4

2. In addition to the bacterial contamination, the secondary data for other parameters such as pH, iron, and arsenic content of water were also referred (Annex B).

3. The fifth filter with Total Coliform 0 CFU/mL in tube- well water was taken as control throughout the study. Filter number 2 and 3 were selected because two households shared the same tube well.

3.2.2 Reinstallation of Filters in Kasiya

- After selecting the tube wells as per the above-mentioned criteria in Kasiya, the reinstallation of the 5 KAF, Gem 505 model were done.

- Reinstallation of the filter was necessary in order to imitate a new filter. Reinstallation was done using thoroughly washed new fine sand, coarse sand and gravel. While other filter components remained the same. The materials

required for reinstalling each 5 filters were:

- KAF, Gem 505 model
- 2 bottles of Piyush
- 6 L gravel (diameter 6.0- 15 mm)
- 4 L coarse sand (diameter 3.0-6.0mm)
- 20- 22 L fine sand (diameter < 1 mm)
- 5 kg non-galvanized iron nails (< 20 length)
- Brick chips (diameter 5-10cm)

Previously used filter components were taken out and filters were emptied. Each filter was washed to get rid of dirt and sand. All new sands and gravel were washed before filling the filter to get rid of very fine particles and clay. Washing process was continued until the water was free of fine particles. Then, for each filter 2 bottles of Piyush (locally manufactured 0.5% chlorine solution) was mixed with 10 L of water. The entire 10L mixture was poured into the empty filter. Then, 6L of gravel (diameter 6.0-15mm) was slowly added to the filter. Gravel layer was flattened with fingers before 4 L coarse sand (diameter 3-6 mm) was slowly added on top of the gravel layer. The coarse sand was flattened as well. Similarly, 20 to 22 L fine sand (diameter < 1 mm) was added and the surface was flattened. Here, each layer was added to water because any air trapped in the filter would clog the system. Previously used 5 kg rusted iron nails (< 20 length) was washed and placed back to the basin. The brick chips were placed onto the surface of iron nails. The basin was inserted into the KAF, which was then closed with the filter lid. The filters were left for 48 hours for Piyush solution to disinfect the sands and gravel layer. After 48 hours, the users of the filter were asked to clean the top layer of sand according to maintenance procedure. 50L of water was poured in the filter to flush the Piyush solution and get rid of chlorine odor. The filter was then ready to use.

- Filter monitoring begun from the first day of filter usage.

- Twelve samples were taken for testing for the first week which are as follows:

Table 3.2 - Water samples to be tested

Water Sample	Bacteria Test	Water Sample	Bacteria Test
KAF No.1 Influent	Yes	KAF No.4 Effluent	Yes
KAF No.1 Effluent	Yes	KAF No.5 Influent	Yes
KAF No.2 Influent	Yes	KAF No.5 Effluent	Yes
KAF No.2 Effluent	Yes	Duplicate Effluent Sample	Yes
KAF No.3 Influent	No	Artificial Contamination	Yes
KAF No.3 Effluent	Yes	Blank	Yes
KAF No.4 Influent	Yes	***Total Number of Tests =***	**12**

- After a week, it was observed that Total Coliform in influent was consistent and number of samples to be tested was reduced accordingly. So influent water was tested once in a week only.

Table 3.3 - Result of Samples tested

Week	Samples to be tested	Total
1.	All 12 samples	12 X 7= 84
2.	Effluent Daily + blank + artificial Influent Weekly	7 X 7= 49 4 X 1= 4
3.	Effluent Daily + blank + artificial Influent Water Weekly	7 X 7= 49 4 X1= 4
4.	Effluent every alternate days + blank + artificial Influent Weekly	7 X 4= 28 4 X 1= 4
Total Number of samples tested in four weeks		**243**

3.3 Total Coliform Tests

Broadly speaking, there are two types of microbial testing methods: qualitative or Presence/ Absence (P/A) tests and quantitative/ enumeration techniques. The Presence and Absence (P/A) tests give yes or no answer to whether certain bacteria are in a water sample and do not indicate its quantity in the water. Therefore, the quantitative Membrane Filter (MF) test was preferred (Purohit, 2004).

3.3.1 M- Endo Broth, Membrane Filter (MF) Test and Incubation

- M- Endo broth is a culture media that selects the growth of Total Coliform. The broth was developed specifically for the growth of Total Coliform and this medium contains lactose as a carbon source inhibitor to suppress growth

of non-coliform. The broth combines the speed of presence/ absence of Total Coliform test with the enumeration of MF. The MF test allows determining the number of Total Coliform in a sample. The membrane filtration test is a fast, simple way to estimate bacterial population in water.

3.3.2 Material Required

The materials that were required for the test of Total Coliform are as follows:

- M-Endo broth
- Portable incubator
- Membrane Filter Unit
- Petri dishes with absorbent pad
- Forceps
- Methanol
- Whirlpack bags
- 0.45- micron filter paper
- 30L bucket
- 1L mug
- Ice pack and cooler
- Distilled water

3.3.3 Procedure as Performed in the Field

- Each day, 30L of fresh influent water was poured to flush the filter before taking any samples. However, it was not possible to fill the filter with 30L all at once. So, 15L of water was poured into the filter at a time. Remaining 15L was poured after the first 15L filtered out.

- After 30L of water was filtered out, fresh filtered water samples were taken. Flushing of filter with 30 L helped to obtain the fresh water sample. However, 15 L was enough to get the fresh water sample from the filter but to be on a safe side, the filter was flushed with 30 L.

- Disposable Whirlpack bags were used for sample collection. Each new bag was sterile and sealed. During sampling, a bag was unsealed, filled up with about 150 mL sample water, and closed. Analysis was performed within 2 hours on the same day as sample collection.

- 3.1g and 1.55g of M-Endo Agar was mixed with 50 ml and 25ml of distilled water respectively and boiled to prepare the required media, according to the method suggested by ENPHO laboratory.

- The working surface was sterilized by burning methanol on it. The top part of the membrane filter unit was sterilized and covered with sterile aluminum paper.

- The top filter part was sterilized between each sample.

- There was one Petri dish maintained per effluent sample, influent water samples, artificial sample, blank sample and duplicate effluent water sample. Blank sample is mineral water sample and artificial sample is artificially contaminated sample with cow dung which are tested at last in order to ensure that the method followed was correct. Duplicate effluent water sample is sample collected twice from a same filter. So, in total 12 samples per day were taken for the first week.

- The lid from a Petri dish containing an absorbent pad was removed. An M-Endo broth was inverted to mix the broth and the cap was removed to pour its content over the absorbent pad. The lid was placed back on the Petri dish.

- The membrane filter assembly was set up. A filter paper, grid side up, was placed into the assembly using sterile forceps. 100 mL of sample was filtered by creating a vacuum below the filter, using the pump-syringe attached to the assembly.

- The filter paper, grid side up, was then transferred on the absorbent pad in the previously prepared Petri dish using sterile forceps. A slight rolling motion was applied during the transfer to avoid air to be trapped in between the pad and the filter paper. The Petri dish lid was replaced.

- The Petri dishes were incubated in the portable Incubator at 35^{o}C to 37°C for 24 hours.

- The Petri dishes were removed from the incubator and colonies were counted, using the grid of the filter to avoid double counting or missing some colonies.

- Red colonies were obtained for Total Coliform and their densities are reported as CFU per 100ml of sample and non-coliform formed colorless colonies.

- The Petri dishes with more than 250 colonies were reported as too numerous to count (TNTC).

The success of the method depended on use of effective differential or selective media that facilitated identification of the bacterial colonies growing on the membrane filter surface. Through out the study period, owners of the filter were asked not to clean the sand of filter, as it would affect the developed biofilm on top of its layer.

3.4 Turbidity Measurement

Turbidity refers to cloudiness of water caused by the suspension of minute particles; usually silt clay etc. It even quantifies the degree to which the light traveling through a water column is scattered by suspended organic or inorganic column.

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 systems leading to waterborne disease outbreaks, which have caused significant cases of gastroenteritis throughout the world. Although, turbidity is not a direct indicator of health risk, numerous studies show a strong relationship between

removal of turbidity and removal of protozoa (Lee, 2001). Turbidity is measured in Nephelometric Turbidity Units (NTU). The WHO guideline for the non- microbial turbidity level in drinking water is set at 5 NTU.

In field, turbidity of influent water as well as effluent water was checked with the help of HACH Portable Turbidity Meter. The portable Turbidity Analysis system measures turbidity in the range from 0.01 to 1000 NTU. It operates on the Nephelometric principle of measurement. The optical system includes a tungsten filament lamp, a 90˚detector to monitor scattered light and a transmitted light detector. The instrument's microprocessor calculated the ratio of the signal from the 90˚and transmitted light detectors. The ratio technique corrects for inference from color and or light absorbing materials (activated carbon) and compensates for fluctuation in lamp intensity, providing long-term calibration stability. The optical design also minimizes stray light, increasing measurement accuracy (HACH Portable Turbidity meter Instrument and Procedure manual, 2001).

3.4.1 Materials Required

- HACH Portable Turbidity Meter
- Sample water
- Cotton

3.4.2 Procedure

- Each day, HACH Portable Turbidity Meter was taken to the field for measuring turbidity of influent and effluent.
- Calibration of the turbidity meter was done so as to minimize the error and it was performed according to the instructions in its manual.
- Turbidity was measured and result was noted down.

3.5 Flow Rate Measurement

Flow Rate measurement is useful at both the sand selection stage and operation stage. At sand selection stage, it indicates whether the sand in the filter is of an appropriate

size. At the operational stage, it indicates if the filter requires maintenance.
It is seen that the biofilm and flow rate of filter have an inverse relationship. As the biofilm thickens the flow rate of the filter decreases. 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 influent. 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 water being treated. Very turbid water, as in the cases of surface water sources during monsoon season, contains a large amount of fine slit, which are trapped in the uppermost layer of sand and biology. The higher the contents of fine slits, the more quickly the filter will clog. Also, if the water contains a large population of biology, the biofilm that feeds on this content will rapidly grow or thicken. This will also result in clogging at the top of the filter. If the rate is too fast, the efficiency of bacterial removal may be reduced. If the flow rate is too slow, there will be an insufficient amount of treated water available from the filter to meet the needs of the users. So it is necessary to check the flow rate of filters.

3.5.1 Materials Required

- 100 mL Plastic Graduated Cylinder
- Stop watch

3.5.2 Procedure

- Flow rate was measured when water level in the basin was full. The flow rate of the filter is related to the amount of water in the filter. It is higher when water level is high above the sand layer and gradually decreases with decrease in water level.

- For consistency in calculation, the flow rate was measured at 5 minutes of pouring water in the filter. At the time, the flow would become steady. Water level in the basin was recorded when measurement is done (should still be full or ¾ full).

The time taken to fill the measuring cylinder of 100 mL was noted down in seconds. Later on sec/100mL was converted into L/hr.

4. Result and Discussion

4.1 Microbial or Total Coliform Results

4.1.1 Filter 1

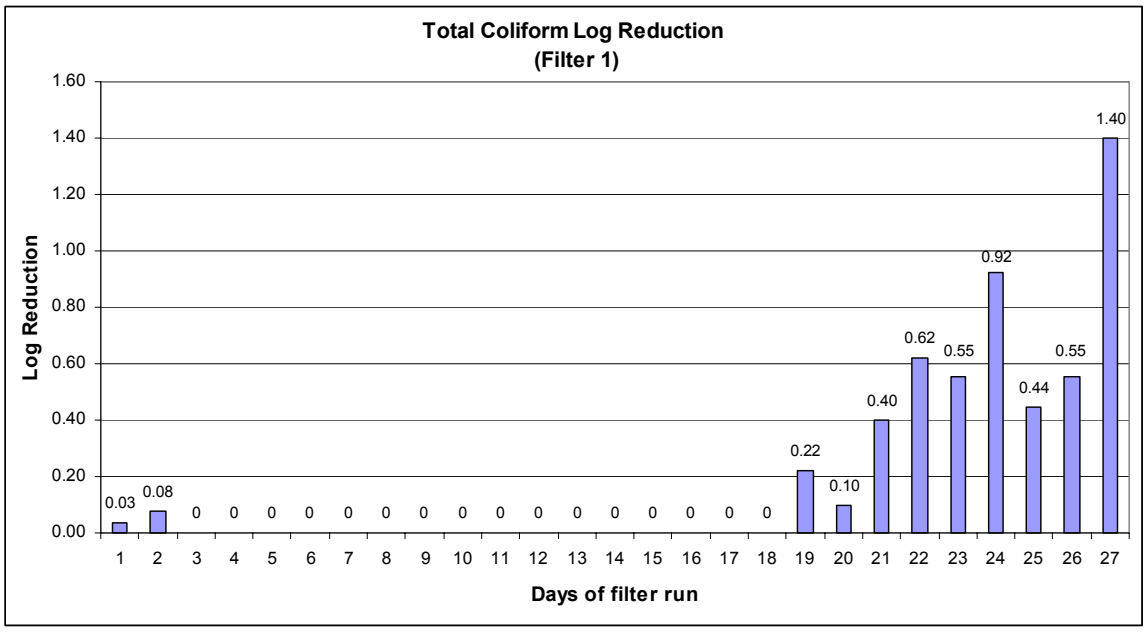


Fig 4.1: Log Reduction Value (LVR) of Total Coliform vs. days of filter run

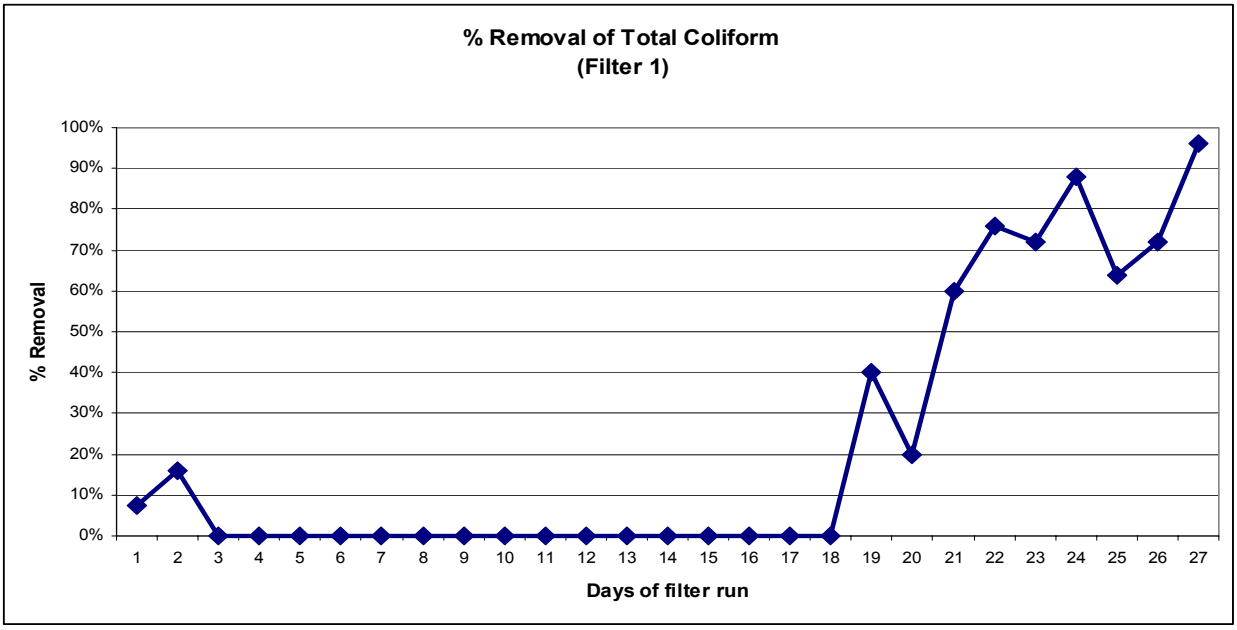


Fig 4.2: Removal of Total Coliform (%) vs. days of filter run

As shown in the above Fig. 4.1 and 4.2, Total Coliform removal for **Filter 1** was in the range of 0 % to 96 % (0 Log Reduction Value to 1.40 Log Reduction Value).

Removal efficiency of the filter remained at 0 % (0 Log Reduction Value) until the eighteenth day and, rose to the value of 96 % (1.40 Log Reduction Value) on the twenty-seventh day of the experimental period.

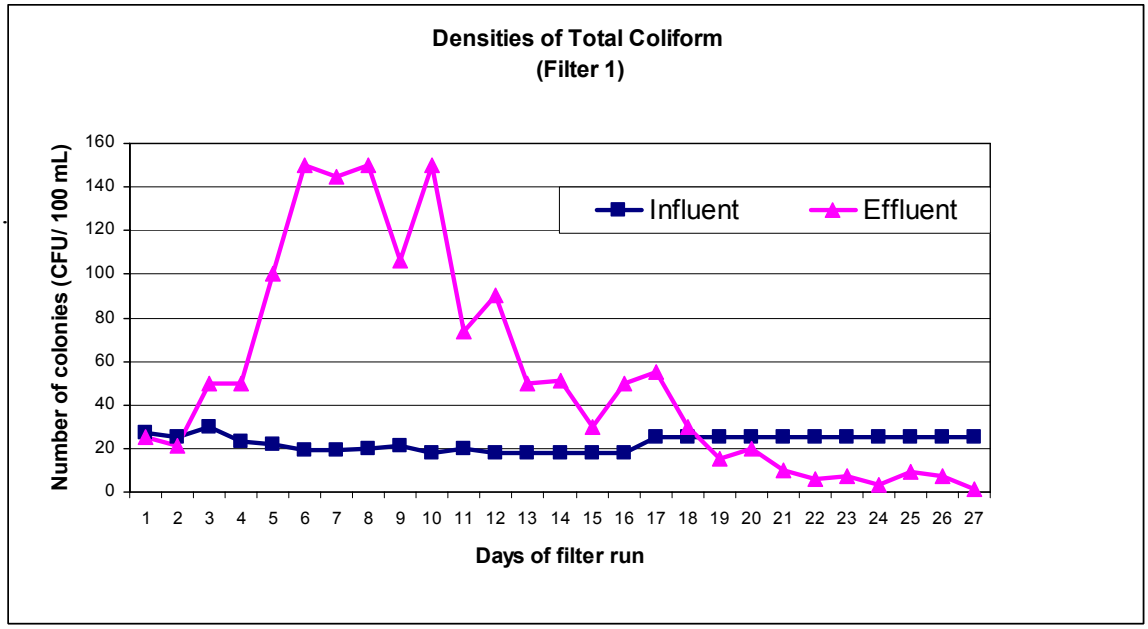
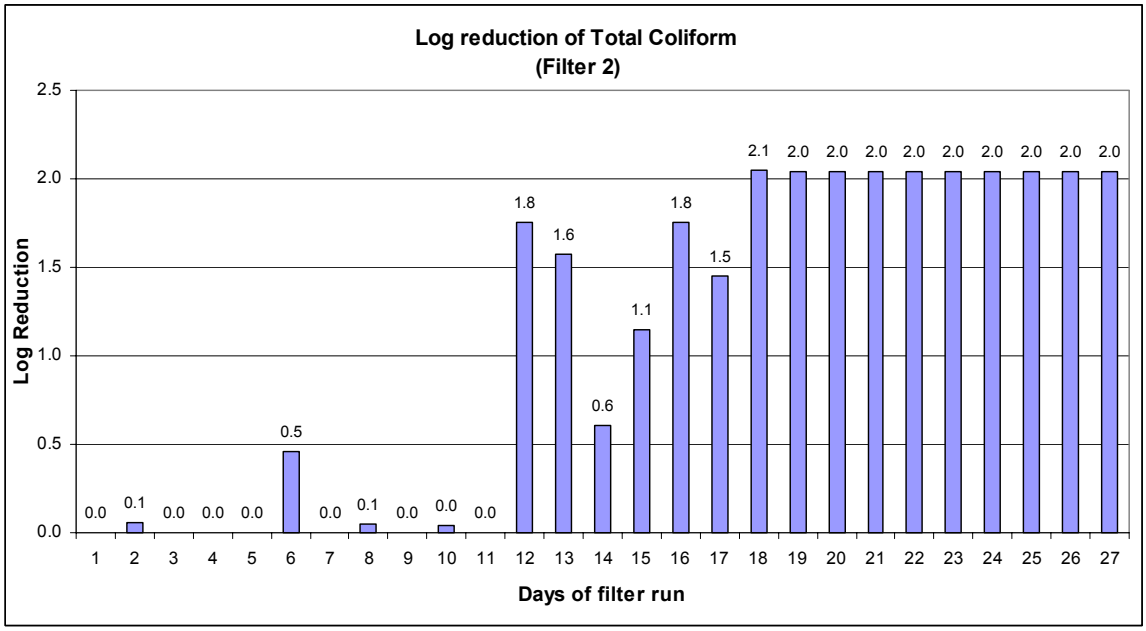


Fig 4.3: Densities of Total Coliform vs. days of filter run

Total Coliform in influent water for **Filter 1** ranged from 18 CFU/ 100mL to 30 CFU/ 100 mL whereas in case of effluent water, the Total Coliform ranged from 1 CFU/ 100 mL to 150 CFU/ 100 mL. The population of Total Coliform in the influent water (average = 23 CFU/100mL) for filter 1 was less than other filters.

The possible reason for not achieving better removal % during the initial period could be due to un- ripened biofilm. The development of biofilm of filter is dependent on many factors such as population of biology in influent, volume of filtered water, nutrients in influent that is necessary for the growth of microorganisms. The population of biology in influent was less. Higher the population of biology, the biological layer that feeds on this content will rapidly grow or thicken. Lastly, the volume of water filtered per day was also less i.e. 14-15 liters. So, this might be another reason for the slower development of biofilm. The population of Total Coliform during the first two days of experiment was 7 and 16 CFU/ 100 mL. The reason for this low concentration of Total Coliform might be due to the remains of Piyush during the installation of filter.

4.1.2 Filter 2



. *Fig 4.4: Log Reduction Value (LVR) of Total Coliform vs. days of filter run*

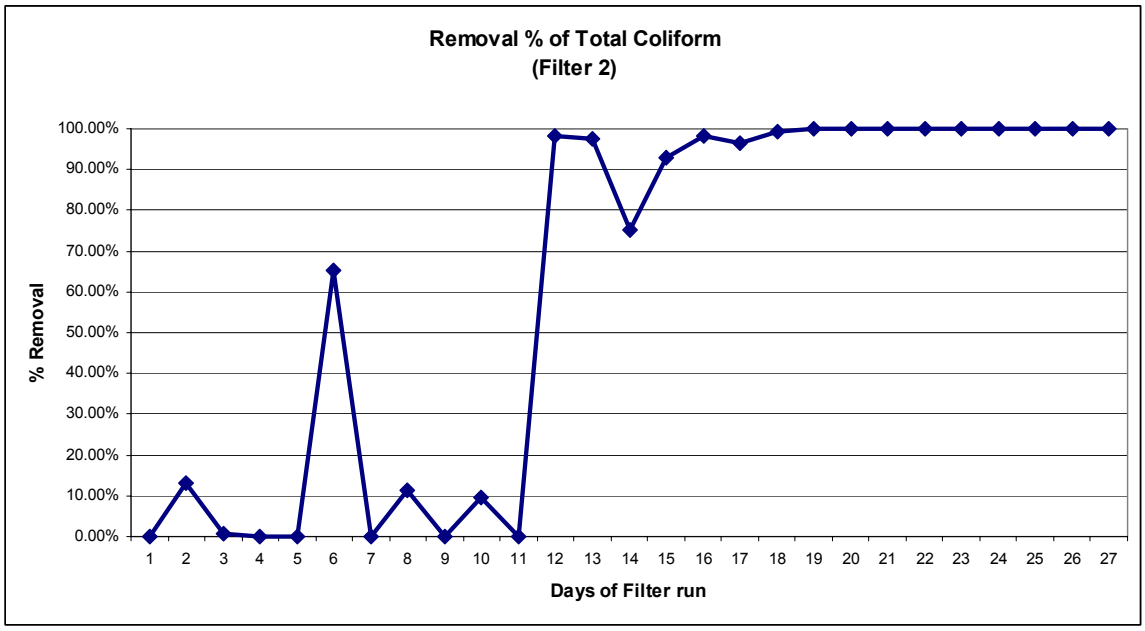


Fig 4.5: Removal of Total Coliform (%) vs. days of filter run

As shown in Fig. 4.4 and 4.5, Total Coliform removal for **Filter 2** was in the range of 0 % to 100 % (0 Log Reduction Value to 2 Log Reduction Value). The removal for the filter remained at 0 % (0 Log Reduction Value) until the eleventh day and, rose to the value of 100 % (2.1 Log Reduction Value) on the nineteenth day of the experimental period. The maturation of biofilm for **Filter 2** was within nineteen days.

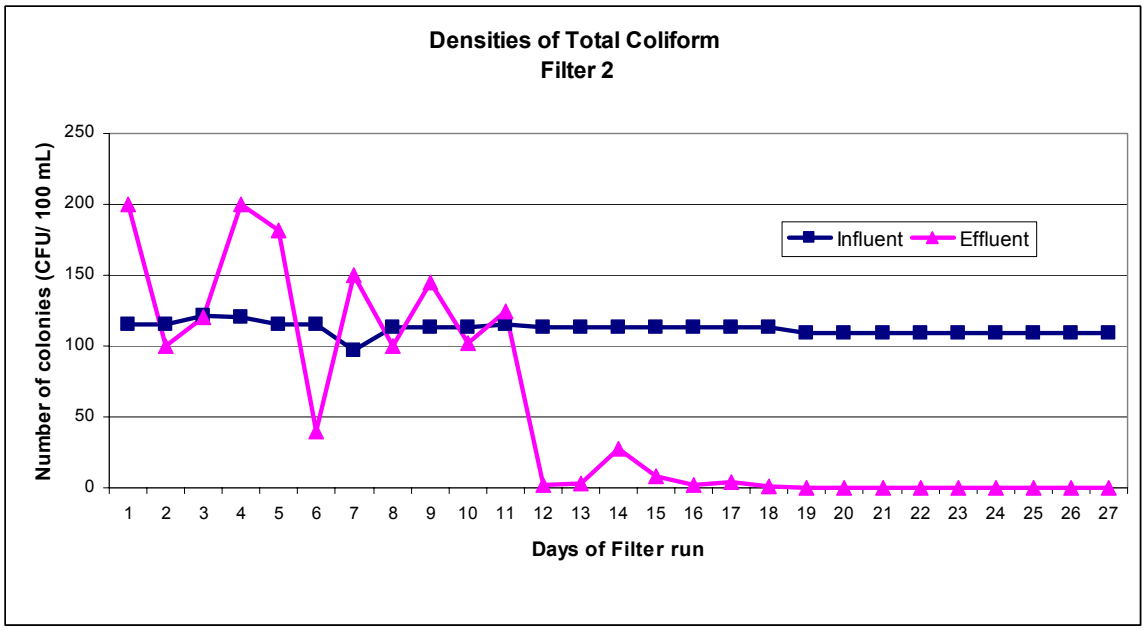


Fig 4.6: Densities of Total Coliform vs. days of filter run

For **Filter 2**, the Total Coliform concentration in influent water ranged from 97 CFU/ 100 mL to 121 CFU/ 100 mL. In case of effluent water, Total Coliform concentration ranged from 0 CFU/100 mL to 200 CFU/ 100 mL.

The removal % was zero during the initial period of the experiment. This might be due to the un-ripened biofilm. During the initial period of the experiment, the users of **Filter 2** used same container to feed their livestock as well as to fill their filter. Also, the container was not cleaned regularly. Inappropriate water handling practice can be another cause for high population of bacteria in the effluent water. The basic education about health and hygiene was given to the users on the tenth day of the experimental period and they were asked to maintain separate containers for filter. With the maintenance of separate container, the pathogen removal efficiency dramatically improved from the eleventh day of the experimental period. Therefore, users education on health and hygiene is crucial and carelessness of users may show low removal efficiency of filters even though the filters itself may have excellent pathogen removal efficiency.

4.1.3 Filter 3

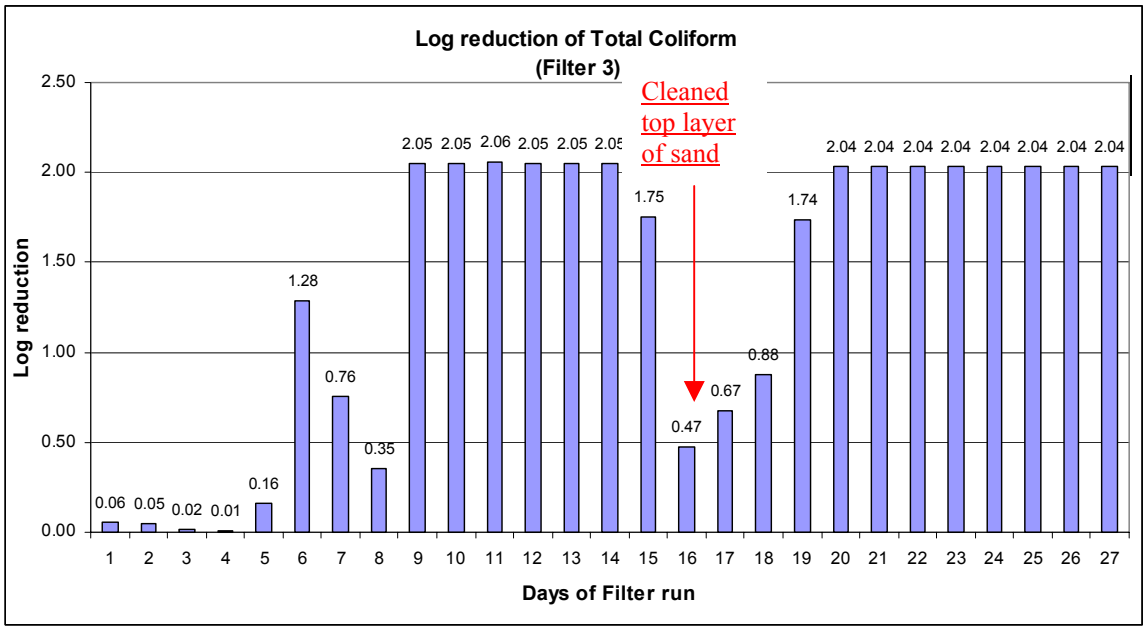


Fig 4.7: Log Reduction Value (LVR) of Total Coliform vs. days of filter run

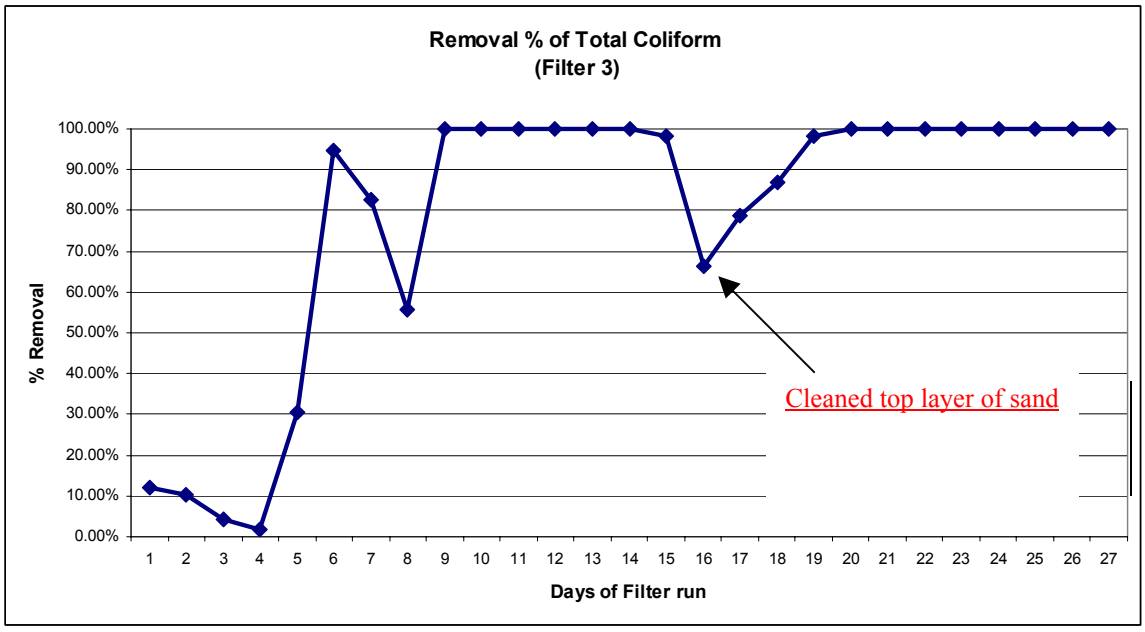


Fig 4.8: Removal of Total Coliform (%) vs. days of filter run

As shown in the Fig. 4.7 and 4.8 Total Coliform removal for **Filter 3** was in the range of 2 % to 100 % (0.01 Log Reduction Value to 2.05 Log Reduction Value). The % removal for the filter increased from 12 % (0.06 Log Reduction Value) from the first day of filter usage to the value of 100 % (2.5 Log Reduction Value) on the ninth day

of the experimental period. The decrease in % removal on the sixteenth day of the experimental period is due to cleaning of top of fine sand, according to the recommended cleaning procedure. Again, the filter showed 100 % (2.04 Log Reduction Value) removal efficiency on the twentieth day of the experimental period. The ripening period for Filter 3 was nine days.

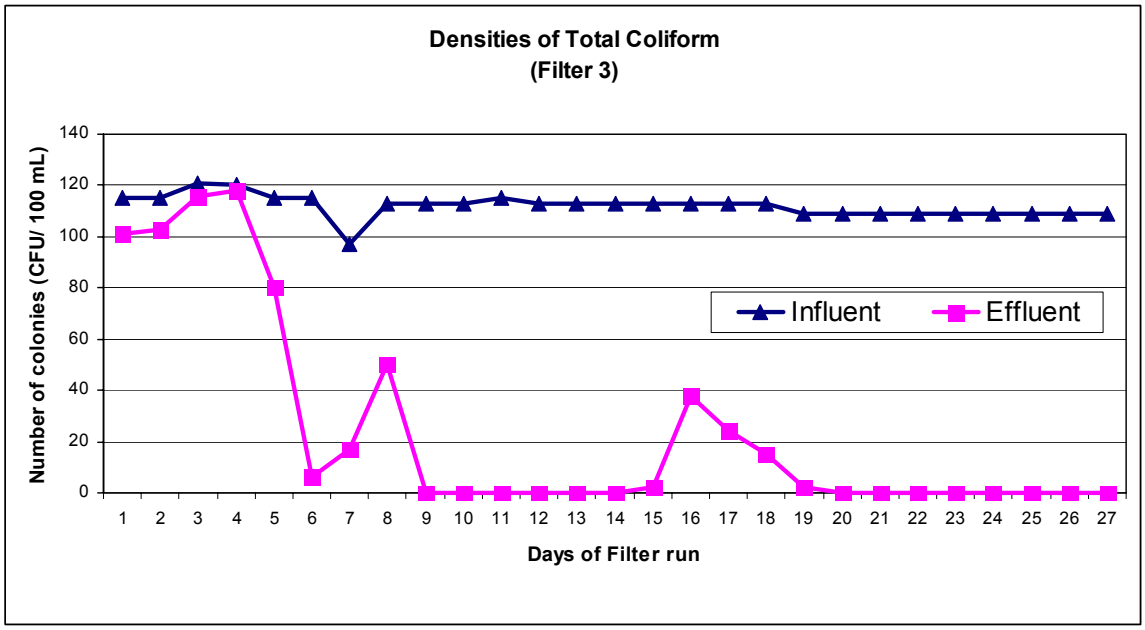


Fig 4.9: Densities of Total Coliform vs. days of filter run

For **Filter 3,** the Total Coliform concentration in influent water ranged from 97 CFU/ 100 mL to 121 CFU/ 100 mL with an average value 112 CFU/ 100 mL. In case of effluent water, Total Coliform concentration ranged from 0 CFU/100 mL to 118 CFU/ 100 mL.

Though, **Filter 3** and **Filter 2** were using same source of influent water, Filter **3** had 100 % removal efficiency within nine days of filter usage, compared to twelve days for Filter **2**. This shows that development of biofilm may be dependent on the volume of water filtered. Because the two households have different number of users and different water needs, the volume of filtered water was about 30L and 50 L per day for filter **2** and **3** respectively. The average biological population of influent water was also higher i.e. >100 CFU/ mL as compared to **Filter 1** and **Filter 5**. Higher population of biology might be another reason for faster development of biofilm. Sudden increase in concentration of Total Coliform in Filter 3 effluent water on

sixteenth day indicates that cleaning of filter destroyed the biofilm and certain time was required for biofilm to mature again. Initially, biofilm had taken a longer time to develop in a newly installed filter but the re-development of biofilm after cleaning was within just four days. This indicates that it takes a longer time in the development of biofilm in the newly installed filter. Whereas once the biofilm has fully matured, the redevelopment of biofilm after being destroyed by filter cleaning can be quick. Assuming that the biofilm was completely destroyed during the cleaning procedure still **Filter 3** showed 66 % or 0.47 Log Reduction Value removal of Total Coliform. Out of 100 % or 2.04 LRV removal of Total Coliform, 66 % of removal of Total Coliform may be due to physical straining and attachment procedures and the rest 34 % removal could be due the matured biofilm.

4.1.4 Filter 4

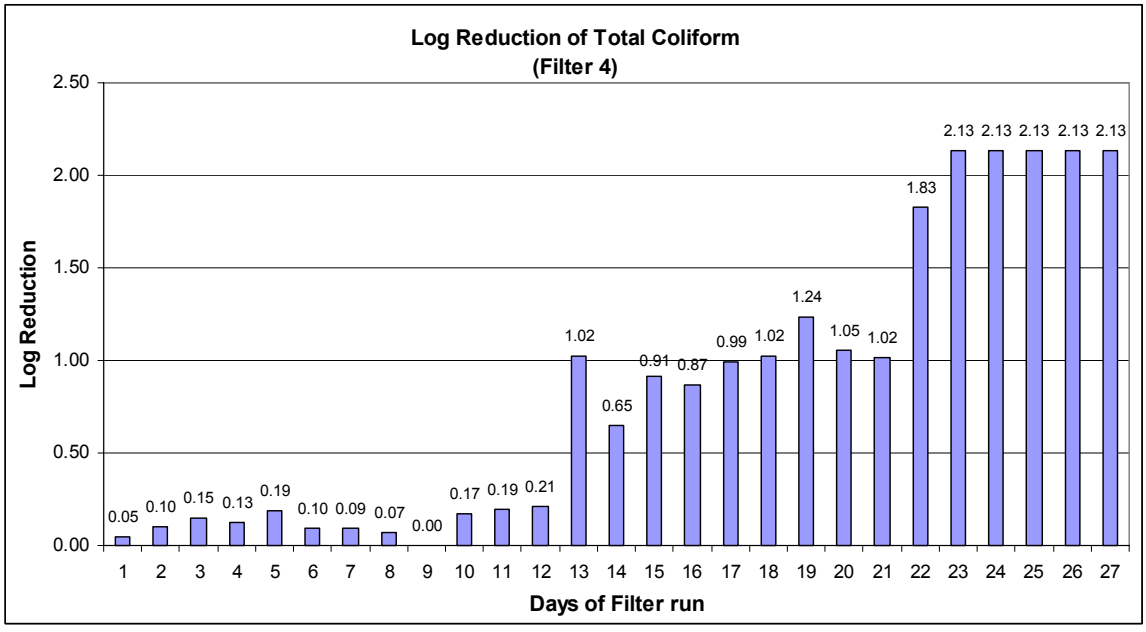


Fig 4.10: Log Reduction Value (LVR) of Total Coliform vs. days of filter run

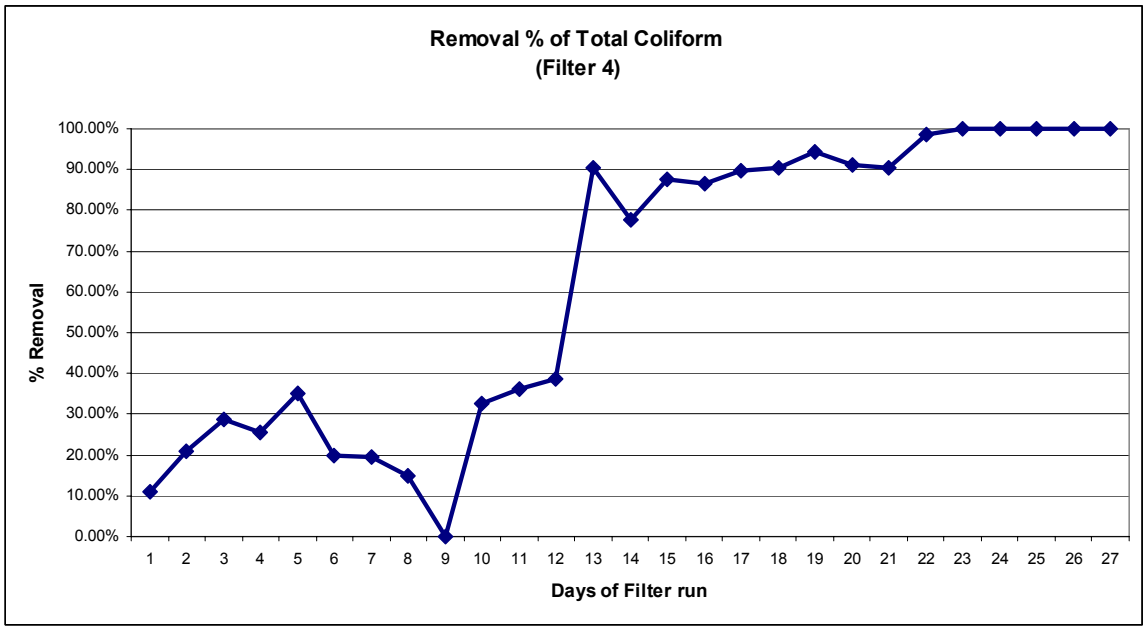


Fig 4.11: Removal of Total Coliform (%) vs. days of filter run

Total Coliform removal for **Filter 4** was in the range of 0 % to 100 % (0 to 2.13 Log Reduction Value). The % removal for the filter increased form 11 % (0.05 Log Reduction Value) from the first day of filter usage to 100 % (2.13 Log Reduction Value) on the twenty-third day of the experimental period.

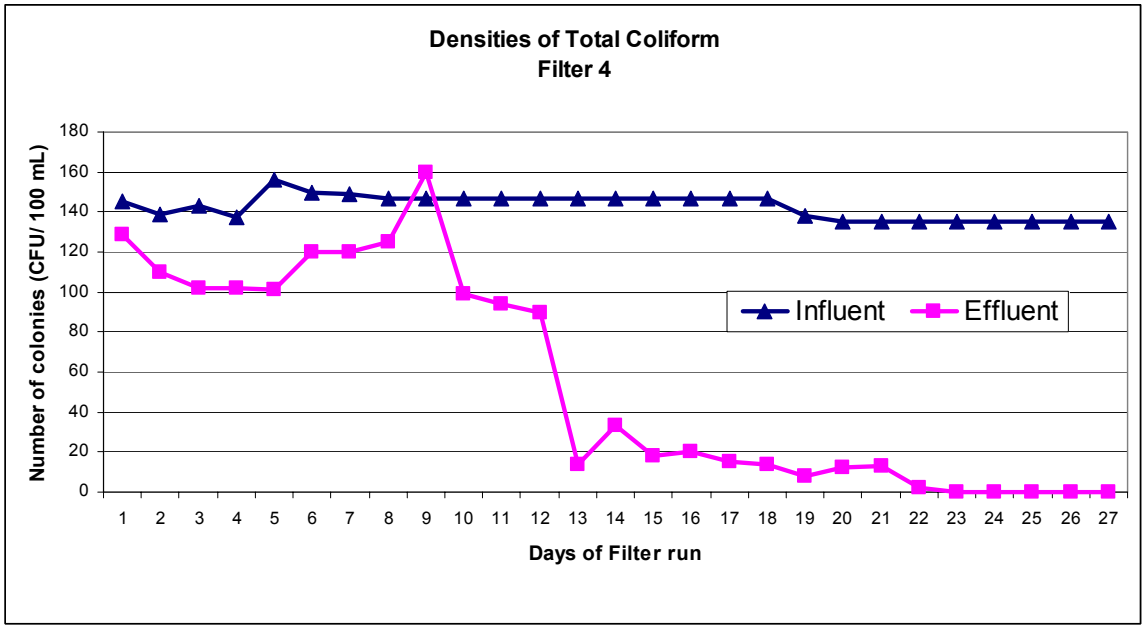


Fig 4.12: Densities of Total Coliform vs. days of filter run

For **Filter 4,** the Total Coliform population in influent water ranged from 135 CFU/ 100 mL to 156 CFU/ 100 mL. In case of effluent water, Total Coliform concentration ranged from 0 CFU/100 mL to 160 CFU/ 100 mL.

Influent water for **Filter 4** had highest average population of biology (i.e.> 140 CFU/ 100 mL) than in any other four filters. Though, it had highest population of biology, the development of biofilm was slower than filter **3**. This might be due to less volume of water filtered per day. However, filter **4** also removes Total Coliform to 0 CFU/ 100 mL as filter **2** and **3.** .

4.1.5 Filter 5

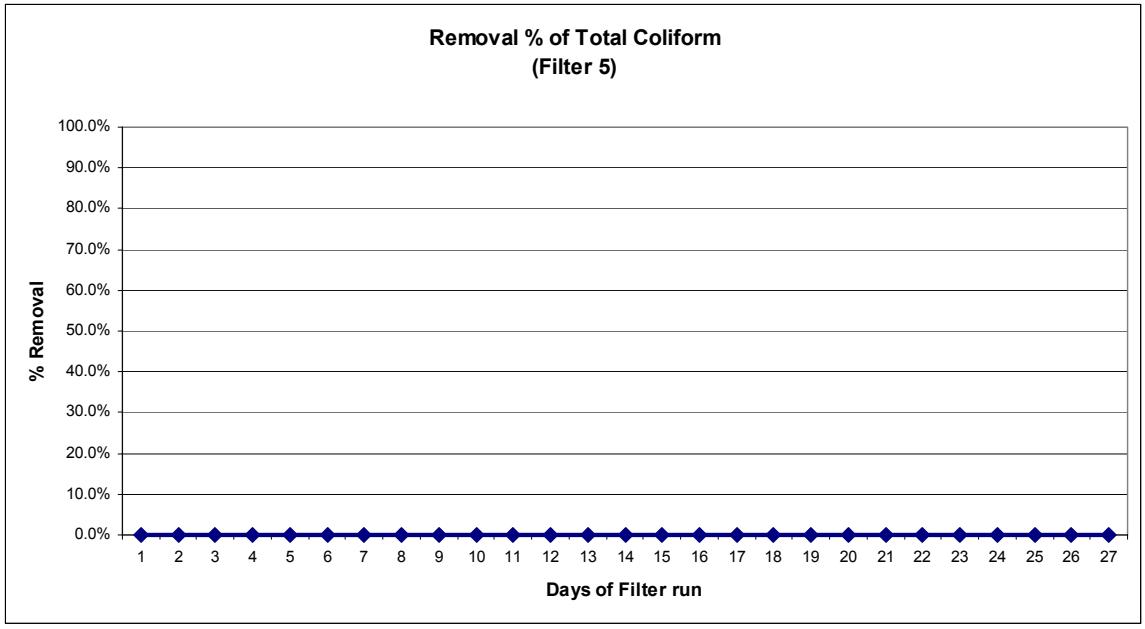


Fig 4.13: Removal of Total Coliform (%) vs. days of filter run

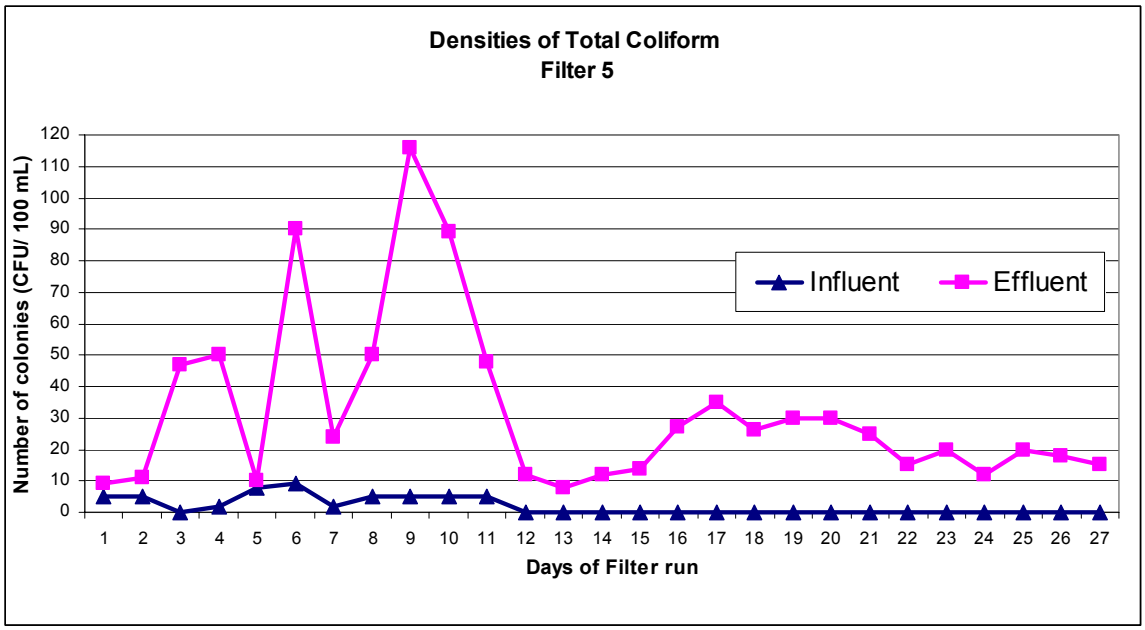


Fig 4.14: Densities of Total Coliform vs. days of filter run

Total Coliform removal for **Filter 5** was 0 % (0 LRV) through out the experimental period.

For **Filter 5,** the Total Coliform concentration in influent water ranged from 0 CFU/ 100 mL to 9 CFU/ 100 mL with an average value 2 CFU/ 100 mL. In case of effluent water, Total Coliform concentration ranged from 8 CFU/100 mL to 116 CFU/ 100 mL.

Influent for **Filter 5** was of high quality. High quality water means water with less amount of organic matter, less turbidity and fewer bacteria in it. So, this high quality water may not contain sufficient nutrients to support elevated growth population of microorganisms. Elevated level of Total Coliform does not necessarily mean that filter **5** was failing to purify contaminated water. Specifically, Total Coliform does not always represent Fecal Coliform in water sample. Besides, Fecal Coliform that is generally found in human and animal intestinal tracks, many other harmless Coliform proliferates in the environment (i.e. in soil, plant and animals). The presence of such bacteria does not necessarily indicate the presence of pathogenic microorganisms (Pincus, 2003). From Filter **5**, it can also be concluded that drop in flow rate does not necessarily contribute to higher bacterial removal efficiency. Though, flow rate was

minimum for Filter **5**, the percent removal efficiency was negative throughout the experimental period.

4.2Turbidity Results

4.2.1 Filter 1

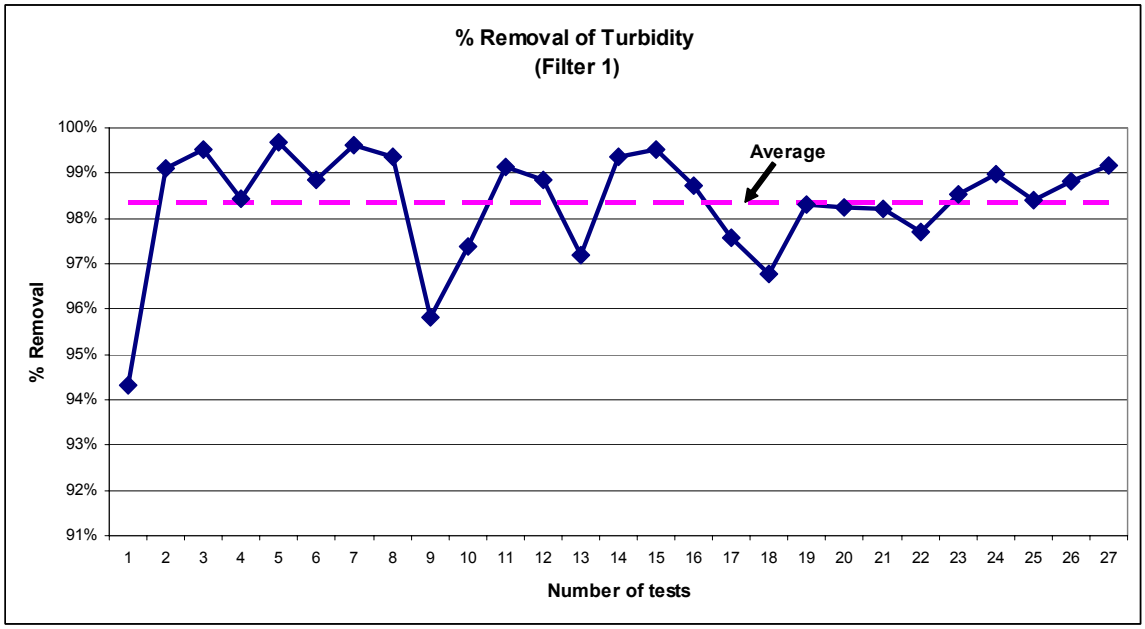


Fig 4.15: Turbidity Removal (%) vs. number of tests

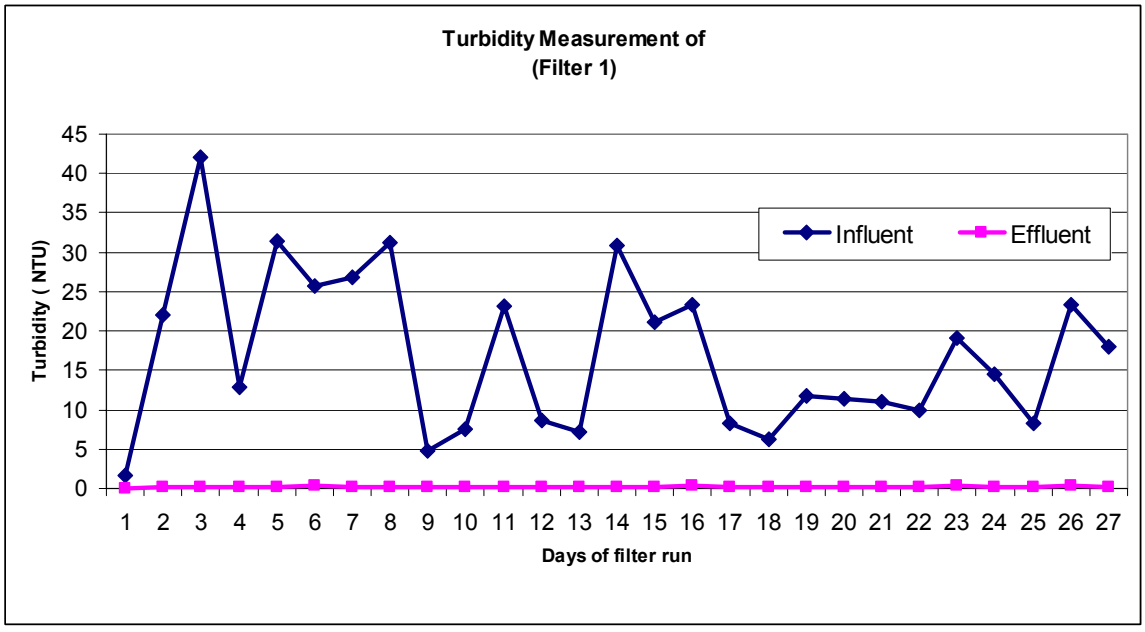


Fig 4.16: Turbidity measurement vs. days of filter run

As shown in Fig 4.15, turbidity removal for **Filter 1** was in the range of 94 % to 100 %. On average, turbidity removal was at 98 %.

For **Filter 1**, turbidity of influent water was in the range of 1.58 NTU to 42.1 NTU with an average value of 17 NTU. In case of effluent water, turbidity was in the range of 0.09 NTU to 0.28 NTU with as average value of 0.2 NTU.

Filter 1 appeared effective in removing turbidity and successfully reduced influent water turbidity to less than 5 NTU. The influent water of Filter **1** was very rich in iron content. Iron in ground water is present in the form of soluble ferrous iron. When soluble ferrous iron comes in contact with air, mainly oxygen, its state is changed to insoluble ferric iron (precipitate). Precipitate of ferric iron is responsible for high turbidity value of influent water. The turbidity of effluent water was always lower than 5 NTU, the WHO guideline for maximum allowable turbidity in drinking water.

4.2.2 Filter 2

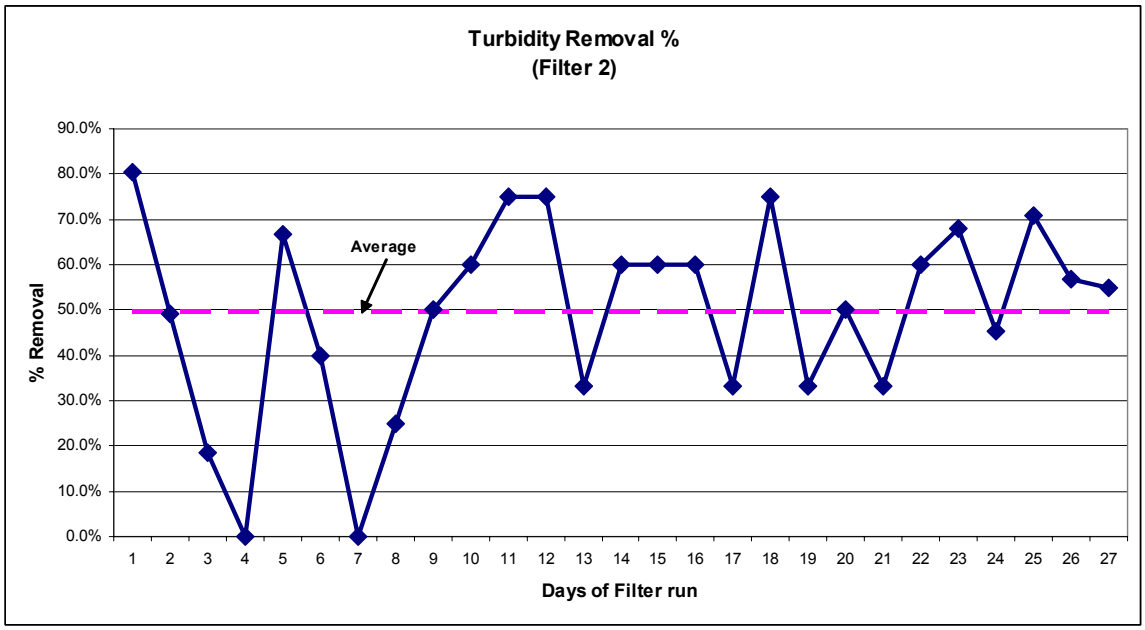


Fig 4.17: Turbidity Removal (%) vs. number of tests

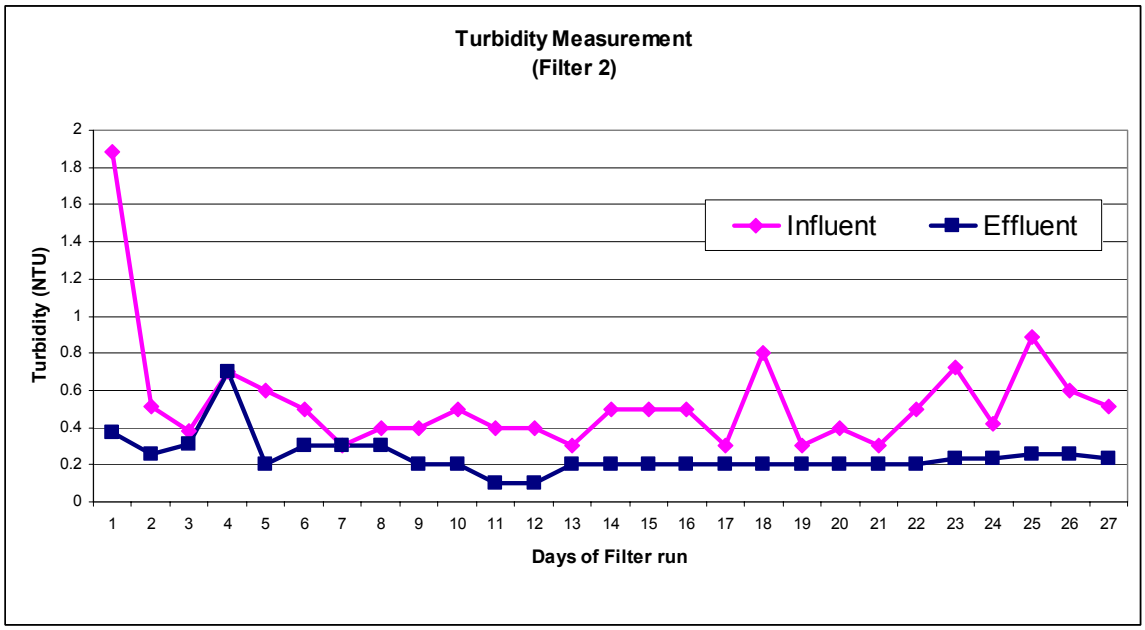


Fig 4.18: Turbidity measurement vs. days of filter run

Turbidity removal for **Filter 2** was in the range of 0 % to 80 %. On average, turbidity removal was at 49 %.

For **Filter 2**, turbidity of influent water was in the range of 0.3 NTU to 2 NTU with an average value of 1 NTU. In case of effluent water, turbidity was in the range of 0.1 NTU to 0.7 NTU with as average value of 0.2 NTU.

For **Filter 2**, influent water was of low turbidity as compared to the influent water of filter **1**. Filter **2** also proved itself equally effective at removing turbidity to less than 5 NTU, WHO guideline for maximum allowable turbidity in drinking water.

4.2.3 Filter 3

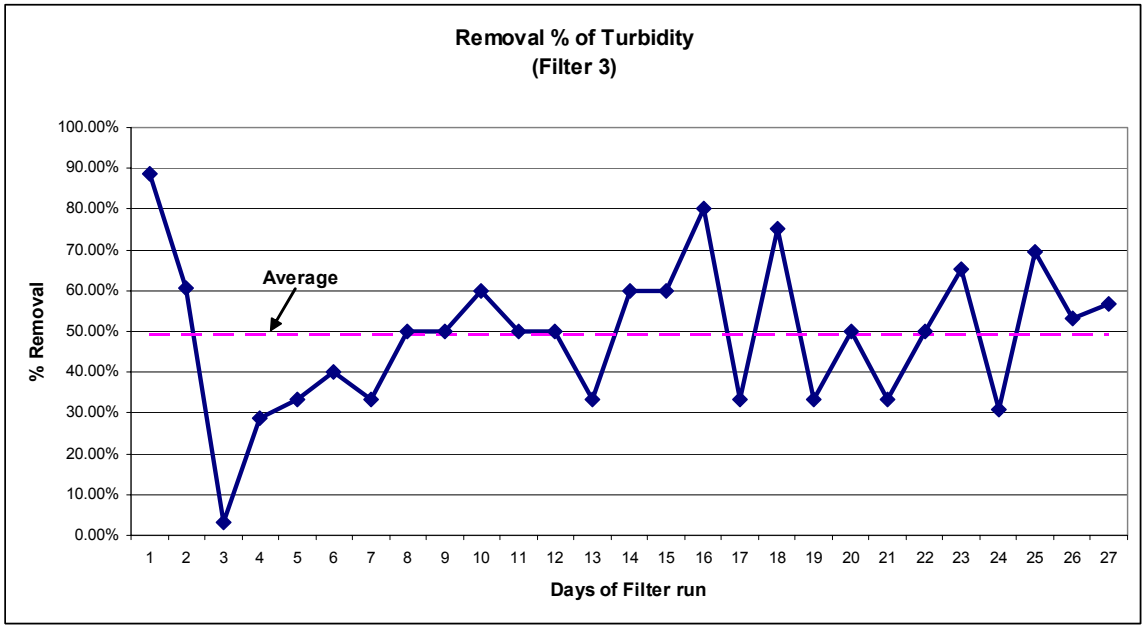


Fig 4.19: Turbidity Removal (%) vs. number of tests

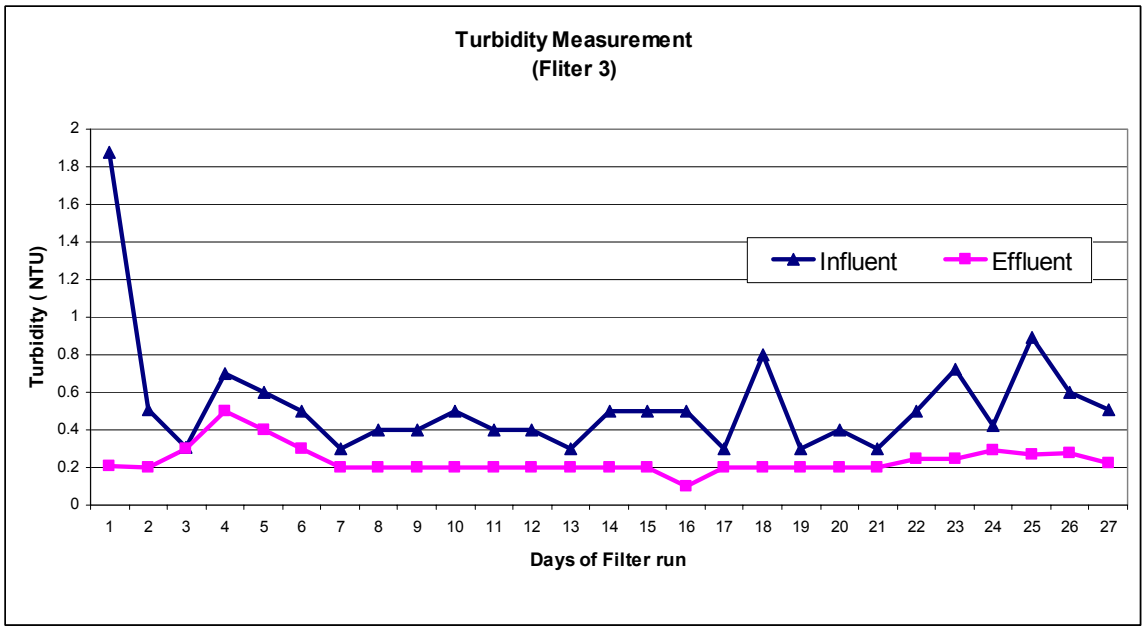


Fig 4.20: Turbidity measurement vs. days of filter run

Turbidity removal for **Filter 3** was in the range of 3 % to 89 %. On average, turbidity removal was at 49 %.

For **Filter 3**, turbidity of influent water was in the range of 0.3 NTU to 4 NTU with an average value of 1 NTU. In case of effluent water, turbidity was in the range of 0.2 NTU to 0.5 NTU with as average value of 0.2 NTU.

Turbidity of influent water for filter **2** and filter **3** was same as both houses used the same tube well for their drinking purpose. **Filter 3** appeared equally effective at removing turbidity as filter **2.** In summary, filter **2** and filter **3** were treating water from same source and had approximately identical turbidity removal.

4.2.4 Filter 4

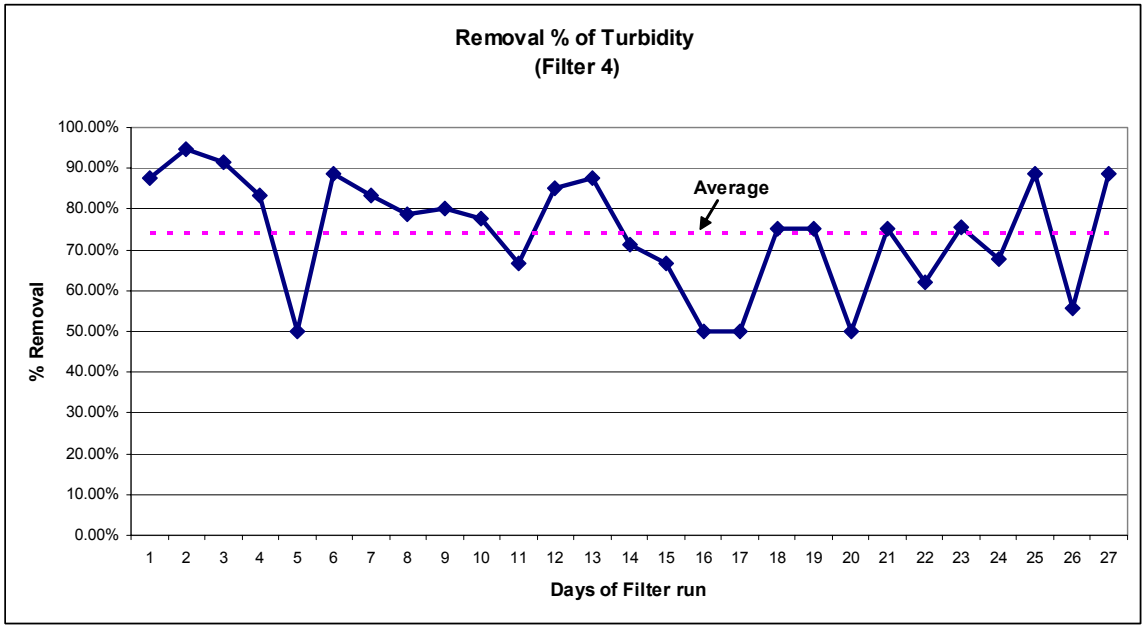


Fig 4.21: Turbidity Removal (%) vs. number of tests

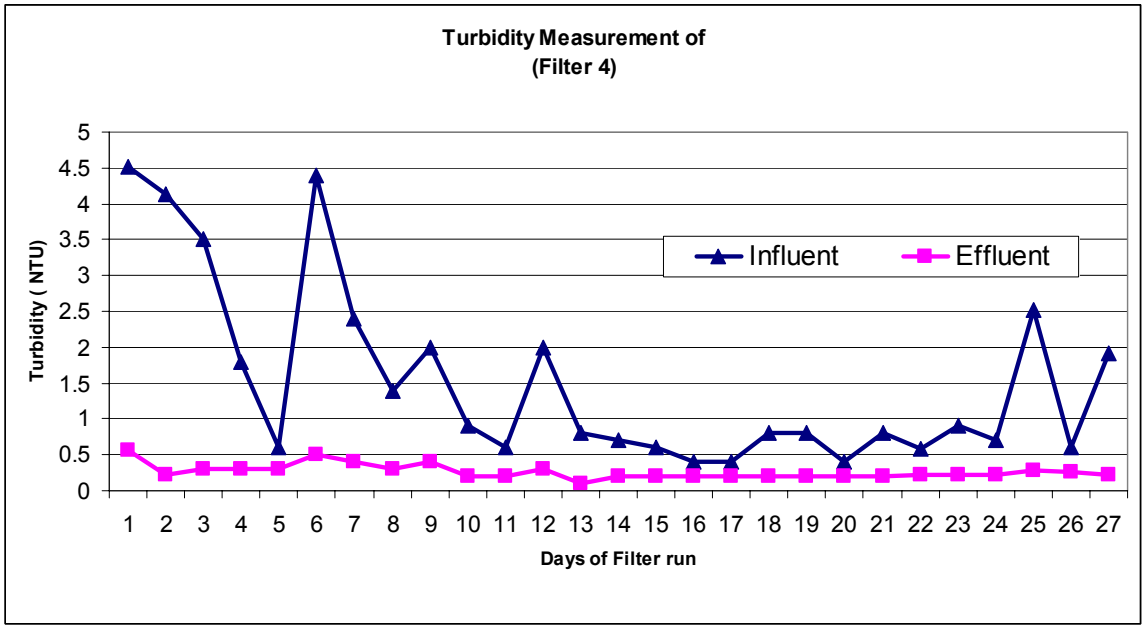


Fig 4.22: Turbidity measurement vs. days of filter run

Turbidity removal for **Filter 4** was in the range of 50 % to 95 %. On average, turbidity removal was at 75 %.

For **Filter 4,** turbidity of influent water was in the range of 0.4 NTU to 5 NTU with an average value of 2 NTU. In case of effluent water, turbidity was in the range of 0.1 NTU to 0.5 NTU with as average value of 0.2 NTU.

The turbidity removal capacity for **Filter 4** was also high. Filter **4** may have been even surpassed both filters **2** and **3** in turbidity removal capacity. It also proved effective at turbidity removal to less than 5 NTU.

4.2.5 Filter 5

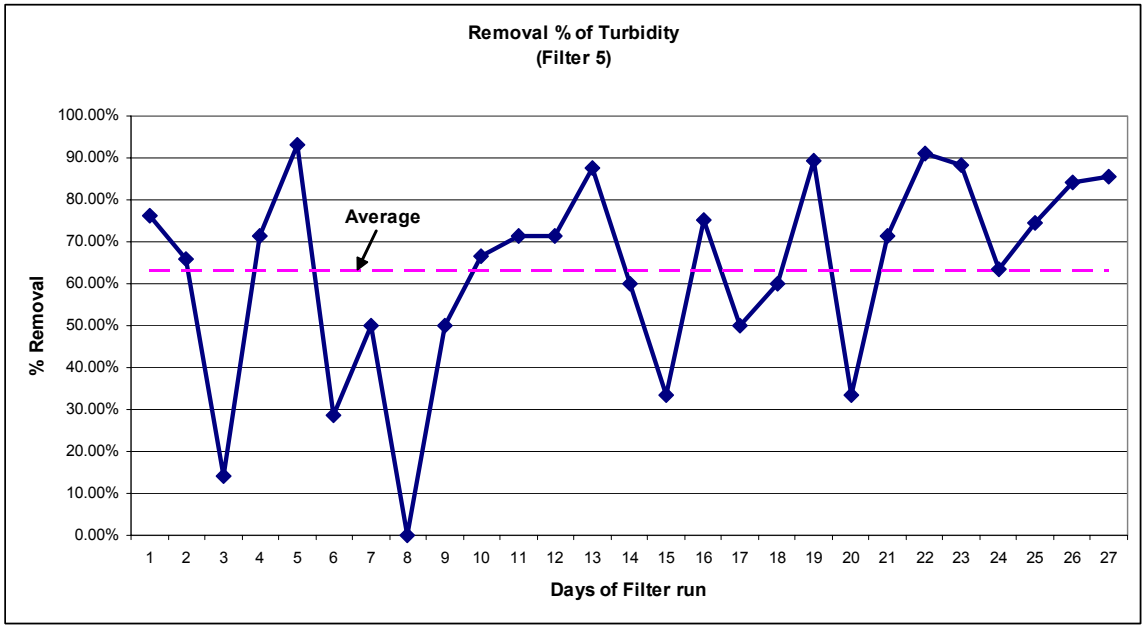


Fig 4.23: Turbidity Removal (%) vs. number of tests

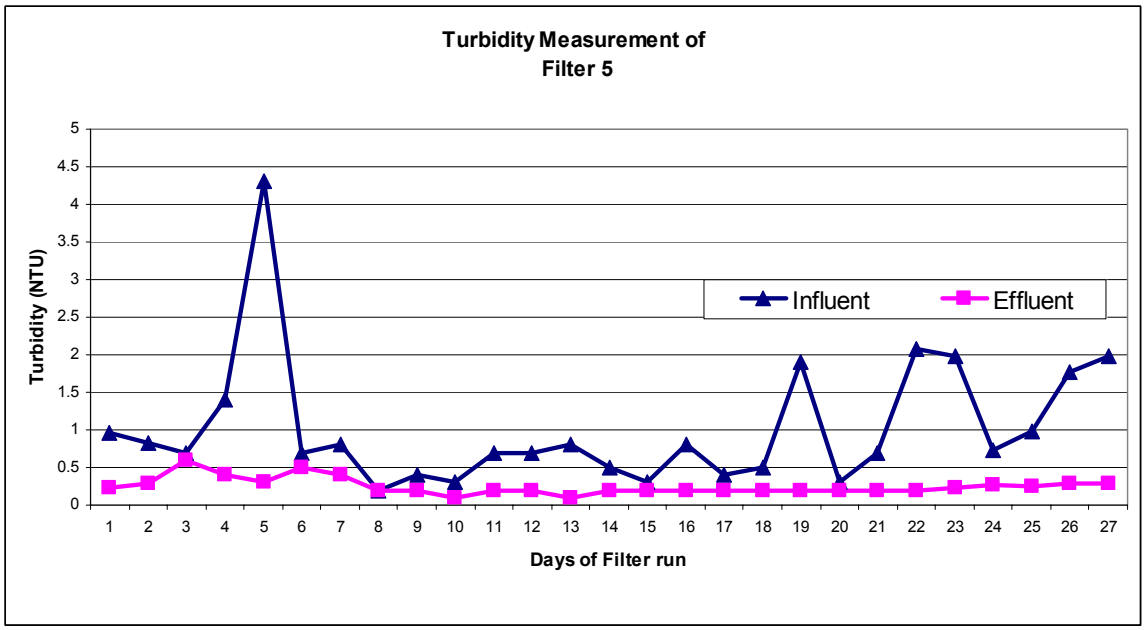


Fig 4.24: Turbidity measurement vs. days of filter run

Turbidity removal for **Filter 5** was in the range of 0 % to 93 %. On average, turbidity removal was at 65 %.

For **Filter 5,** turbidity of influent water was in the range of 0.2 NTU to 4 NTU with an average value of 1 NTU. In case of effluent water, turbidity was in the range of 0.1 NTU to 0.5 NTU with as average value of 0.2 NTU.

Filter 5 was quite efficient at removing suspended particles from influent. It too, proved its capability in removing turbidity to less than 5 NTU.

In summary, though the turbidity for influent water varied considerably, all five filters were quite effective at removing suspended particles from influent water. All five filters proved effective at removing turbidity to less than 5 NTU, WHO guideline for maximum allowable turbidity of drinking water.

4.3 Flow Rate Results

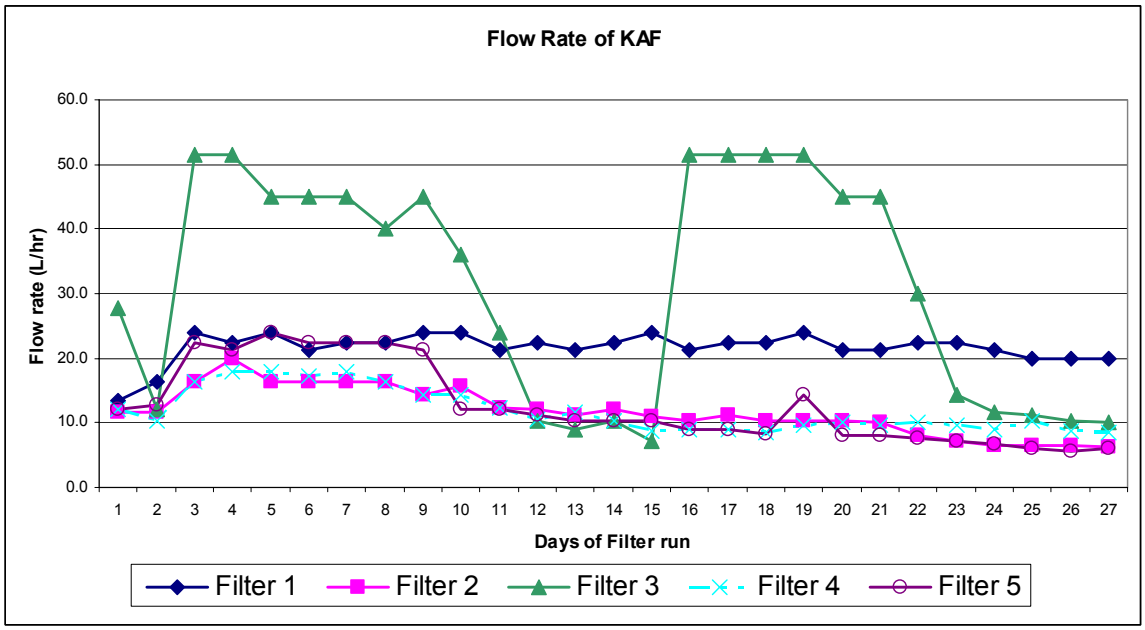


Fig 4.25: Flow Rate of KAF vs. days of filter run

For **Filter 1**, flow rate increased from 13 L/hr on first day of filter usage to 24 L/hr on third day and subsequently decreased to 20 L/hr on twenty-seventh day of the experimental period. The average flow rate during the experimental period was at 22 L/hr.s

For filter **1**, flow rate decreased very slightly over the experimental period for a month. As iron nails were not used in the filter, iron rust from nails played no role in clogging of filter. As a result, the decrease in the flow rate could be attributed to high iron content, fine particles, silt and dust in influent water. The average flow rate of the filter was 22 L/hr; it means the users did not need to waits for long to obtain the water for cooking and drinking purpose.

For **Filter 2,** flow rate increased from 12 L/hr on first day of filter usage to maximum value 20 L/hr on fourth day of the experiment and finally decreased to 6 L/hr on twenty- seventh day of the experiment, a 50 % reduction over a period of twenty- six days. The average flow rate during the experimental period was 12 L/hr.
This 50% reduction in flow rate may be due to fine particles, dust, and iron that clog the filter. Again, influent water for filter **2** contains population of biology, too. These

biological populations in influent water help in the faster development of biofilm that in turn reduces the flow rate of the filter. A 2003 study by World Health Organization (WHO) concluded that a minimum of 7.5 L water per capita per day is necessary to meet basic consumption and basic hygiene needs (WHO, 2003). The average family size of Terai is 6 (District Demographic Profile of Nepal, 2002). Therefore, the daily need of 6 members of the family can be met by running the filter for 12 hours per day even when the flow rate drops down to 4 L/ hr.

For **Filter 3**, flow rate increased from 28 L/hr from first day of experiment to maximum value of 51 L/hr on third day of the experiment. Finally, the flow rate again decreased to 10 L/hr with a reduction of 64 % over the period of twenty-six day days of the experiment. The average flow rate of the filter over the experimental period is 31 L/hr.

Filter **3** had highest initial flow rate as compared to other filter because users had cleaned iron nails as well as brick chips to clear it from dust and rust. Even, the basin was washed with all its holes cleared out to get rid from iron sludge/ dirt. Where as, other users cleaned only the basin components such as iron nails and bricks but they didn't clear out the holes of the basin. Slow flow rates could also result from lack of users' education and insufficient washing of sand, too. The graph explains decrease in flow rate till fifteenth day of the experiment and increase in flow rate again from sixteenth day of the experimental period. This was mainly due to cleaning of top of fine sand of the filter as the recommended cleaning procedure that was carried out to explain the relationship of biofilm with flow rate. And, it was concluded that biofilm and flow rate has inverse relationship. As biofilm was damaged during the cleaning operation, flow rate increased. The further decrease in flow rate till the twenty-seventh day of the experiment may be due to the high amount of effluent, sufficient for 9 members in the family. The average value of filter **3** was 31 L/hr and was capable of providing sufficient water for this household of 9 members.

For **filter 4**, flow rate increased from 12 L/hr from first day of experimental period to the maximum value of 18 L/hr on fourth day of the experimental period and finally decreased to 9 L/hr, a 25 % reduction over the experimental period of twenty- six days. The average flow rate during the experimental period was 12 L/hr.

Influent water for filter **4** was high in turbidity as compared to that of **Filters 2**& **3** and it even contained large population of biology than any other four filters. Higher the population of biology, faster is the development of biofilm, which results in a kind of clogging at the top of fine sand of the filter. The decrease in flow rate could be attributed due to sand, dust and iron particles and arsenic removal unit in influent as well as due to high population of biology. The average flow rate of the filter was 12 L/hr which means that their daily minimum need of 7.5 L each of 8 members could be met by running the filter for 5 hours/ day.

Flow Rate for **filter 5** increased from 12 L/hr from first day of the experimental period to the maximum value of 24 L/hr on the fifth day of the experiment and finally decreased to 6 L/hr on twenty- seventh day of the experimental period, a 73 % reduction over the course of experiment of twenty- six days. The average flow rate of the filter during the experimental period was 13 L/hr.

The explanation for the low rate of this filter, especially when compared to other similar four filters, was that the fine sand used in this filter is finer than the other four filters. Another explanation for the low flow rate is mainly due to fine particles, slit, sand and iron that clog the filter. The influent water for filter **5** was with no population of biology and lower the population of biology, the slower is the development of biofilm on top of sand layer. The clogging of filter **5** due to development of biofilm was minimal as compared to other filters. The average flow rate of the filter was 13 L/hr which means that their daily minimum need of 7.5 L each of 4 members could be met by running the filter for 2 and half hours/ day.

In summary, high initially flow rate of filters was mainly due to newly installed loose sand layer. These loose sand layers have high porosity or void space. Over time sand compaction occurred, which reduced the porosity and flow rate decreased. Secondly, decrease in flow rate was due to turbidity of water. Higher the turbidity in influent water the sooner the filter will clog. Also, high population of biology in influent water may cause faster growth of biofilm, which in turn results in clogging at the top of the fine sand layer in the filter, thus decreases the flow rate. Higher flow rate can be obtained by cleaning the sand layer but frequent cleaning/ maintenance of filter can

damage the biofilm. If there is not enough time for the biofilm to mature again (i.e. 4 days based on this study), the effectiveness of the KAF can be reduced. Moreover, higher flow rate can even be obtained by filling the basin to full level.

4.4 Social Acceptance of Filter

Though major focus of the study was on technical evaluation of KAF, but social aspect is also an important criterion to assess the appropriateness and sustainability of a technology. Based on informal interaction with the users, the users of the filter seemed very happy with the performance of filter. In addition, some reported improved health and reduced illness following filter introduction. First, they like the filter's ability to remove yellow color due to iron, typical odor of ground water and foul taste. They were also satisfied with the high filtration rate, simple operation, minimal maintenance and capital cost of the filter. The actual cost of KAF, Gem 505 is about Rs. 1400 but they are sold to the villagers at a highly subsidized rate. They are charged according to the users' ability and willingness to pay.

Kasiya village communities appeared to be interested in and accepting the KAF technology. Many other villagers also expressed an interest in acquiring KAF, Gem 505 model and filter users were generally eager to learn cleaning and maintenance protocol again. Most users think that KAF is a durable and appropriate solution to arsenic, iron and pathogen removal (Ngai, 2003).

4.5 Problems Encountered During the Experimental Period

- Cooler ice packs were not available as there was no refrigerator. As such, the time between sample collection and analysis was minimized as far as possible. Efforts were made so that all the samples collected were analyzed with in 1-$1^{1/2}$ hours between sample collection and analysis.

- Low level of power transmission during peak evening hours was a major problem. Insufficient power transmission to the incubator was usually

observed during evenings. During such time, the temperature would drop down to 22˚−25˚C and would again resume to normal during late nights.

- Due to political development of county, the experimental period was restricted to a month.

5. Conclusion

KAF can be taken as the effective solution for pathogen and turbidity removal. Total Coliform removal efficiency was excellent for filter **2, 3** and **4** with the maximum value of 100% attained after eighteen, eight and twenty- two days respectively. The Total Coliform removal efficiency was good for filter **1** with maximum value of 96% attained after twenty- six days and worst for filter **1** at 0 %. The 0 % removal efficiency for filter **5** verifies that the effectiveness of filter performance differs with the quality of influent water being treated.

From turbidity measurements of influent water as well as effluent of KAF, it was found that the turbidity removal of all five KAFs averaged 67 %. All the filters proved themselves efficient at removing turbidity of influent water. The average effluent water turbidity was 0.23 NTU which is less than 5 NTU, the WHO maximum guideline for turbidity of drinking water.

Flow rate measurement of effluent water of all five KAFs yielded an average of 18 L/hr which means that KAFs were capable of providing adequate supply of drinking water of 7.5 L per person, the WHO guideline which is the minimum amount of water that a person requires per day.

Table 5.1: Summary of Technical Performance of KAFs during the experimental period

Technical Parameter	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5
Total Coliform, Influent water (CFU/100 mL)	18 - 30	97 - 121	97 - 121	135 -156	0 -9
Total Coliform, Effluent water (CFU/ 100 mL)	1 - 150	0 - 200	0 -118	0 -160	8 -116
% Total Coliform removal	0% - 96%	0% - 100%	2% -100%	0% - 100%	0%
Turbidity, Influent water (NTU)	1.58-42.1	0.3- 2.0	0.3- 2.0	0.4- 5.0	0.2 -4.0
Turbidity, Effluent water (NTU)	0.09-0.28	0.1 – 0.7	0.2 – 0.5	0.1 – 0.5	0.1 – 0.6
% Turbidity Removal	94% - 100%	0%- 80%	3%- 89%	50%- 95%	0%-93%
Flow Rate (L/ hr)	13 -24	6 - 20	9 -51	9- 18	6 - 24
Log Reduction Value	0- 1.40	0 – 2.1	0.01 – 2.04	0 – 2.13	0

About the social acceptance of the filter, the users liked the clarity and taste of the effluent. They pointed out that effluent water was without peculiar smell that ground water has and was cool. Some of them claimed reduced health problems after drinking the effluent water. They are satisfied with the filtration rate and simple maintenance of the filter.

6. Recommendation

- Providing filters for families is a necessary condition for improving health of people. However, providing filters alone is not sufficient; it does not improve the health of the users if their practices are unhygienic. Personal habits, handling of water and the overall environment around a household also affect hygiene and health. So, basic education to the filter users on health and hygiene is a must in order to improve their health status.

- Participation of female members in any tutorials related with filter use is important. Females are responsible for providing water to household. Unless the females have knowledge for proper utilization of filter and the filter operation techniques, improved health status of any household cannot be expected. Involvement of at least one female from a household is must to improve the health status of whole community.

- Evaluation of filter should be done from time to time to check the performance of filter. So, regular monitoring of filter performance is recommended.

- A tube well designated, as safe upon one time testing in an affected area cannot be presumed permanently safe. Hence, continuous monitoring is required. Government should provide training to local people who would help prepare a network of human resource in each community at field level for arsenic testing as well as for its mitigation program.

- The lack of a proper clean container for collecting effluent in most of the houses is a common issue. To solve this problem a plastic storage bucket with a lid could be provided together with the filter. A bucket along with a filter will certainly increase the price of the filter, but on the other hand will add on to good health of the users.

- Community awareness campaigning program should not only focus on the dreadful effects of arsenic poisoning, but also on balanced and nutritious food

intake and other healthy habits such as quit smoking, which help to reduce ill effects of arsenic. Arsenocosis patients should be advised to take more protein and vitamins rich food such as beans, pulses, soybeans, seasonal fruits and green vegetables (Neku and Tandukar, 2002). Green coriander is highly recommended to be eaten.

- For Filter 5, further research is recommended to see whether the coliform growth is inside the filter, or it is the apparent coliform growth due to other issues such as poor sanitary, hygiene, and handling practice.

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8. Annex

8.1 Annex A

Definitions of the Terms Used During the Experiment

Flow Rate (sec/100mL): This term denotes the time required is seconds to fill the graduated cylinder of 100 mL.

Liter/ hour: The time obtained which is in seconds to fill a graduated cylinder of 100 mL in converted to L / hr.

15 sec → 100 mL
1 sec → 100 mL / 15
1 mL → 1000 L
L/ hr → 100/ 15 * 1000/ 3600 = 24 L

% Removal of Total Coliform: {(TC in influent water – TC in effluent water)/ TC in influent water} X 100%

% Removal of Turbidity: {(Turbidity of influent water- Turbidity of effluent water)/ Turbidity of influent water} X 100%

Log Reduction Value (LRV): $\log_{10}$(raw water Total Coliform concentration / filtered water Total Coliform concentration)
1 LRV = 90%, 2 LRV = 99% and 3 LRV = 99.9% reduction.

8.2 Annex B

Secondary Data Referred During the Filter Selection Process.

Date	Filter Number	User's name	Arsenic (ppb)		Iron (ppm)		pH		Remarks
			Tube Well	Filtered water	Tube Well	Filtered Water	Tube Well	Filtered Water	
Aug 2004	1	Ganesh Harijan	10	0	3	0	7.1	7.4	
Aug 2004	2	Swami Nath Yadav	300	0	0.3	0	7.4	7.7	
Aug 2004	3	Ghama Pr.Chaudhari	300	0	0.3	0	7.4	7.7	
Aug 2004	4	Madav Lal Shrestha	300	0	0.3	0	7	7.5	
Aug 2004	5	Sudarshan Chaudhari	400	0	0.3	0	7.2	7.6	
Sep 2004	1	Ganesh Harijan	10	0	3	0	6.8	7.2	
Sep 2004	2	Swami Nath Yadav	400	-	0	-	7.5	-	Filter Broken
Sep 2004	3	Ghama Pr.Chaudhari	400	0	0	0	7.5	7.6	
Sep 2004	4	Madav Lal Shrestha	400	0	0.3	0	7.5	8	
Sep 2004	5	Sudarshan Chaudhari	400	0	0.3	0	7.5	7.9	

Source: ENPHO 2004

8.3 Annex C

Field Test Results (Filter 1)

User's Name: Ganesh Harijan

		Total Coliform (cfu/100ml)				Turbidity (NTU)			Flow Rate	
Date	Filter No.	Influent	Effluent	% Removal	Log Reduction Value	Influent	Effluent	% Removal	ml/sec	L/hr
6/3/2005	1	27	25	7.41%	0.03	1.58	0.09	94.3%	27	13.3
7/3/2005	1	25	21	16.00%	0.08	22	0.2	99.1%	22	16.4
8/3/2005	1	30	50	0.00%	0.00	42.1	0.2	99.5%	15	24.0
9/3/2005	1	23	50	0.00%	0.00	12.8	0.2	98.4%	16	22.5
10/3/2005	1	22	100	0.00%	0.00	31.5	0.1	99.7%	15	24.0
11/3/2005	1	19	150	0.00%	0.00	25.8	0.3	98.8%	17	21.2
12/3/2005	1	19	145	0.00%	0.00	26.9	0.1	99.6%	16	22.5
13/3/2005	1	20	150	0.00%	0.00	31.3	0.2	99.4%	16	22.5
14/3/2005	1	21	106	0.00%	0.00	4.8	0.2	95.8%	15	24.0
15/3/2005	1	18	150	0.00%	0.00	7.6	0.2	97.4%	15	24.0
16/3/2005	1	20	74	0.00%	0.00	23.2	0.2	99.1%	17	21.2
17/3/2005	1	18	90	0.00%	0.00	8.6	0.1	98.8%	16	22.5
18/3/2005	1	18	50	0.00%	0.00	7.1	0.2	97.2%	17	21.2
19/3/2005	1	18	51	0.00%	0.00	30.9	0.2	99.4%	16	22.5
20/3/2005	1	18	30	0.00%	0.00	21.2	0.1	99.5%	15	24.0
21/3/2005	1	18	50	0.00%	0.00	23.4	0.3	98.7%	17	21.2
22/3/2005	1	25	55	0.00%	0.00	8.2	0.2	97.6%	16	22.5
23/3/2005	1	25	30	0.00%	0.00	6.2	0.2	96.8%	16	22.5
24/3/2005	1	25	15	40.00%	0.22	11.8	0.2	98.3%	15	24.0
25/3/2005	1	25	20	20.00%	0.10	11.3	0.2	98.2%	17	21.2
26/3/2005	1	25	10	60.00%	0.40	11.1	0.2	98.2%	17	21.2
27/3/2005	1	25	6	76.00%	0.62	9.99	0.23	97.7%	16	22.5
28/3/2005	1	25	7	72.00%	0.55	19.09	0.28	98.5%	16	22.5
29/3/2005	1	25	3	88.00%	0.92	14.5	0.15	99.0%	17	21.2
30/3/2005	1	25	9	64.00%	0.44	8.21	0.13	98.4%	18	20.0
31/3/2005	1	25	7	72.00%	0.55	23.4	0.28	98.8%	18	20.0
1/4/2005	1	25	1	96.00%	1.40	18.03	0.15	99.2%	18	20.0

Field Test Results (Filter 2)

User's Name: Swami Nath Yadav

		Total coliform (cfu/100ml)				Turbidity (NTU)			Flow Rate	
Date	Filter No.	Influent	Effluent	% Removal	Log Reduction Value	Influent	Effluent	% Removal	mL/sec	L/hr
6/3/2005	2	115	200	0.00%	0.0	1.88	0.37	80.3%	31	11.61
7/3/2005	2	115	100	13.04%	0.1	0.51	0.26	49.0%	31	11.61
8/3/2005	2	121	120	0.83%	0.0	0.38	0.31	18.4%	22	16.36
9/3/2005	2	120	200	0.00%	0.0	0.7	0.7	0.0%	18	20.00
10/3/2005	2	115	182	0.00%	0.0	0.6	0.2	66.7%	22	16.36
11/3/2005	2	115	40	65.22%	0.5	0.5	0.3	40.0%	22	16.36
12/3/2005	2	97	150	0.00%	0.0	0.3	0.3	0.0%	22	16.36
13/3/2005	2	113	100	11.50%	0.1	0.4	0.3	25.0%	22	16.36
14/3/2005	2	113	145	0.00%	0.0	0.4	0.2	50.0%	25	14.40
15/3/2005	2	113	102	9.73%	0.0	0.5	0.2	60.0%	23	15.65
16/3/2005	2	115	124	0.00%	0.0	0.4	0.1	75.0%	29	12.41
17/3/2005	2	113	2	98.23%	1.8	0.4	0.1	75.0%	30	12.00
18/3/2005	2	113	3	97.35%	1.6	0.3	0.2	33.3%	32	11.25
19/3/2005	2	113	28	75.22%	0.6	0.5	0.2	60.0%	30	12.00
20/3/2005	2	113	8	92.92%	1.1	0.5	0.2	60.0%	33	10.91
21/3/2005	2	113	2	98.23%	1.8	0.5	0.2	60.0%	35	10.29
22/3/2005	2	113	4	96.46%	1.5	0.3	0.2	33.3%	32	11.25
23/3/2005	2	113	1	99.12%	2.1	0.8	0.2	75.0%	35	10.29
24/3/2005	2	109	0	100.00%	2.0	0.3	0.2	33.3%	35	10.29
25/3/2005	2	109	0	100.00%	2.0	0.4	0.2	50.0%	35	10.29
26/3/2005	2	109	0	100.00%	2.0	0.3	0.2	33.3%	36	10.00
27/3/2005	2	109	0	100.00%	2.0	0.5	0.2	60.0%	45	8.00
28/3/2005	2	109	0	100.00%	2.0	0.72	0.23	68.1%	50	7.20
29/3/2005	2	109	0	100.00%	2.0	0.42	0.23	45.2%	55	6.55
30/3/2005	2	109	0	100.00%	2.0	0.89	0.26	70.8%	56	6.43
31/3/2005	2	109	0	100.00%	2.0	0.6	0.26	56.7%	55	6.55
1/4/2005	2	109	0	100.00%	2.0	0.51	0.23	54.9%	57	6.32

Field Test Results (Filter 3)

User's Name: Ghama Prashad Chaudhari

		Total Coliform (cfu/100ml)				Turbidity			Flow Rate	
Date	Filter No	Influent	Effluent	% Removal	Log Reduction Value	Influent	Effluent	% Removal	mL/sec	L/hr
6/3/2005	3	115	101	12.17%	0.06	1.88	0.21	88.83%	13	27.69
7/3/2005	3	115	103	10.43%	0.05	0.51	0.2	60.78%	30	12.00
8/3/2005	3	121	116	4.13%	0.02	0.31	0.3	3.23%	7	51.43
9/3/2005	3	120	118	1.67%	0.01	0.7	0.5	28.57%	7	51.43
10/3/2005	3	115	80	30.43%	0.16	0.6	0.4	33.33%	8	45.00
11/3/2005	3	115	6	94.78%	1.28	0.5	0.3	40.00%	8	45.00
12/3/2005	3	97	17	82.47%	0.76	0.3	0.2	33.33%	8	45.00
13/3/2005	3	113	50	55.75%	0.35	0.4	0.2	50.00%	9	40.00
14/3/2005	3	113	0	100.00%	2.05	0.4	0.2	50.00%	8	45.00
15/3/2005	3	113	0	100.00%	2.05	0.5	0.2	60.00%	10	36.00
16/3/2005	3	115	0	100.00%	2.06	0.4	0.2	50.00%	15	24.00
17/3/2005	3	113	0	100.00%	2.05	0.4	0.2	50.00%	35	10.29
18/3/2005	3	113	0	100.00%	2.05	0.3	0.2	33.33%	40	9.00
19/3/2005	3	113	0	100.00%	2.05	0.5	0.2	60.00%	35	10.29
20/3/2005	3	113	2	98.23%	1.75	0.5	0.2	60.00%	50	7.20
21/3/2005	3	113	38	66.37%	0.47	0.5	0.1	80.00%	7	51.43
22/3/2005	3	113	24	78.76%	0.67	0.3	0.2	33.33%	7	51.43
23/3/2005	3	113	15	86.73%	0.88	0.8	0.2	75.00%	7	51.43
24/3/2005	3	109	2	98.17%	1.74	0.3	0.2	33.33%	7	51.43
25/3/2005	3	109	0	100.00%	2.04	0.4	0.2	50.00%	8	45.00
26/3/2005	3	109	0	100.00%	2.04	0.3	0.2	33.33%	8	45.00
27/3/2005	3	109	0	100.00%	2.04	0.5	0.25	50.00%	12	30.00
28/3/2005	3	109	0	100.00%	2.04	0.72	0.25	65.28%	25	14.40
29/3/2005	3	109	0	100.00%	2.04	0.42	0.29	30.95%	31	11.61
30/3/2005	3	109	0	100.00%	2.04	0.89	0.27	69.66%	32	11.25
31/3/2005	3	109	0	100.00%	2.04	0.6	0.28	53.33%	35	10.29
1/4/2005	3	109	0	100.00%	2.04	0.51	0.22	56.86%	36	10.00

Field Test Results (Filter 4)

User's Name: Madav Lal Shrestha

		Total Coliform (cfu/100ml)				Turbidity (NTU)			Flow Rate	
Date	Filter #	Influent	Effluent	% Removal	Log Reduction Value	Influent	Effluent	% Removal	mL/sec	L/hr
6/3/2005	4	145	129	11.03%	0.05	4.51	0.56	87.58%	30	12
7/3/2005	4	139	110	20.86%	0.10	4.14	0.22	94.69%	35	10.29
8/3/2005	4	143	102	28.67%	0.15	3.5	0.3	91.43%	22	16.36
9/3/2005	4	137	102	25.55%	0.13	1.8	0.3	83.33%	20	18
10/3/2005	4	156	101	35.26%	0.19	0.6	0.3	50.00%	20	18
11/3/2005	4	150	120	20.00%	0.10	4.4	0.5	88.64%	21	17.14
12/3/2005	4	149	120	19.46%	0.09	2.4	0.4	83.33%	20	18
13/3/2005	4	147	125	14.97%	0.07	1.4	0.3	78.57%	22	16.36
14/3/2005	4	147	160	0.00%	0.00	2	0.4	80.00%	25	14.4
15/3/2005	4	147	99	32.65%	0.17	0.9	0.2	77.78%	25	14.4
16/3/2005	4	147	94	36.05%	0.19	0.6	0.2	66.67%	29	12.41
17/3/2005	4	147	90	38.78%	0.21	2	0.3	85.00%	34	10.59
18/3/2005	4	147	14	90.48%	1.02	0.8	0.1	87.50%	31	11.61
19/3/2005	4	147	33	77.55%	0.65	0.7	0.2	71.43%	35	10.29
20/3/2005	4	147	18	87.76%	0.91	0.6	0.2	66.67%	41	8.78
21/3/2005	4	147	20	86.39%	0.87	0.4	0.2	50.00%	40	9
22/3/2005	4	147	15	89.80%	0.99	0.4	0.2	50.00%	40	9
23/3/2005	4	147	14	90.48%	1.02	0.8	0.2	75.00%	42	8.571
24/3/2005	4	138	8	94.20%	1.24	0.8	0.2	75.00%	37	9.73
25/3/2005	4	135	12	91.11%	1.05	0.4	0.2	50.00%	36	10
26/3/2005	4	135	13	90.37%	1.02	0.8	0.2	75.00%	37	9.73
27/3/2005	4	135	2	98.52%	1.83	0.58	0.22	62.07%	36	10
28/3/2005	4	135	0	100.00%	2.13	0.9	0.22	75.56%	37	9.73
29/3/2005	4	135	0	100.00%	2.13	0.71	0.23	67.61%	40	9
30/3/2005	4	135	0	100.00%	2.13	2.52	0.29	88.49%	35	10.29
31/3/2005	4	135	0	100.00%	2.13	0.61	0.27	55.74%	41	8.78
1/4/2005	4	135	0	100.00%	2.13	1.92	0.22	88.54%	42	8.571

Field Test Results (Filter 5)

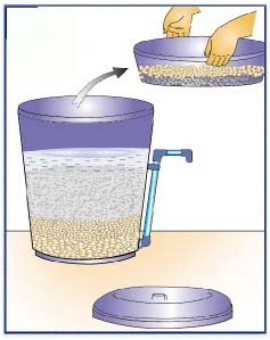
User's Name: Sudarshan Chaudhari

Date	Filter #	Total Coliform (cfu/100ml)			Turbidity (NTU)			Flow Rate	
		Influent	Effluent	% Removal	Influent	Effluent	% Removal	mL/sec	L/hr
6/3/2005	5	5	9	0.0%	0.97	0.23	76.29%	30	12.00
7/3/2005	5	5	11	0.0%	0.82	0.28	65.85%	28	12.86
8/3/2005	5	0	47	0.0%	0.7	0.6	14.29%	16	22.50
9/3/2005	5	2	50	0.0%	1.4	0.4	71.43%	17	21.18
10/3/2005	5	8	10	0.0%	4.3	0.3	93.02%	15	24.00
11/3/2005	5	9	90	0.0%	0.7	0.5	28.57%	16	22.50
12/3/2005	5	2	24	0.0%	0.8	0.4	50.00%	16	22.50
13/3/2005	5	5	50	0.0%	0.2	0.2	0.00%	16	22.50
14/3/2005	5	5	116	0.0%	0.4	0.2	50.00%	17	21.18
15/3/2005	5	5	89	0.0%	0.3	0.1	66.67%	30	12.00
16/3/2005	5	5	48	0.0%	0.7	0.2	71.43%	30	12.00
17/3/2005	5	0	12	0.0%	0.7	0.2	71.43%	32	11.25
18/3/2005	5	0	8	0.0%	0.8	0.1	87.50%	35	10.29
19/3/2005	5	0	12	0.0%	0.5	0.2	60.00%	35	10.29
20/3/2005	5	0	14	0.0%	0.3	0.2	33.33%	35	10.29
21/3/2005	5	0	27	0.0%	0.8	0.2	75.00%	40	9.00
22/3/2005	5	0	35	0.0%	0.4	0.2	50.00%	40	9.00
23/3/2005	5	0	26	0.0%	0.5	0.2	60.00%	43	8.37
24/3/2005	5	0	30	0.0%	1.9	0.2	89.47%	25	14.40
25/3/2005	5	0	30	0.0%	0.3	0.2	33.33%	45	8.00
26/3/2005	5	0	25	0.0%	0.7	0.2	71.43%	45	8.00
27/3/2005	5	0	15	0.0%	2.08	0.19	90.87%	47	7.66
28/3/2005	5	0	20	0.0%	1.99	0.23	88.44%	50	7.20
29/3/2005	5	0	12	0.0%	0.74	0.27	63.51%	53	6.79
30/3/2005	5	0	20	0.0%	0.98	0.25	74.49%	60	6.00
31/3/2005	5	0	18	0.0%	1.77	0.28	84.18%	65	5.54
1/4/2005	5	0	15	0.0%	1.99	0.29	85.43%	60	6.00

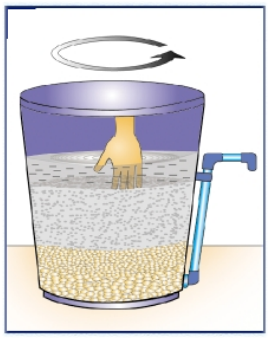
8.4 Annex D

Kanchan™ Arsenic Filter Cleaning Procedure

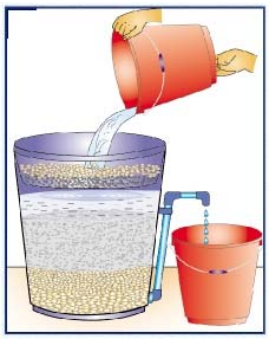
1) Wash your hands with soap.



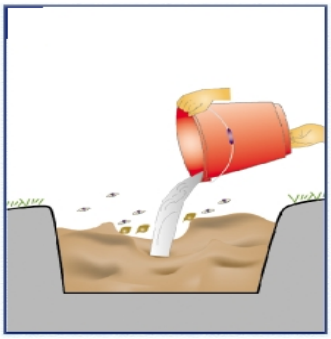
2) Remove diffuser basin.



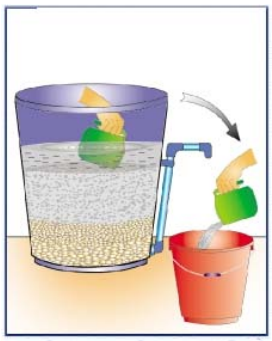
3) Stir the uppermost ½ inch of sand with your fingers.



4) Replace turbid water with a cup. Replace the basin & add more water. Repeat the stirring process for 2 additional time.



5) Discard the turbid water in a dug hole with some cow dung in it.



6) Now the filter can be used again.

Source: KAF booklet, ENPHO 2005.

8.5 Annex E

List of Plates

Plate 1: Collecting Filtered water sample

Plate 2: Reinstallation of filter

Plate 3: HACH Portable Turbidity Meter

Plate 4: Tube well

Plate 5: Millipore incubator

Plate 6: Collecting filtered water

Plate 7: Flow rate measurement

Plate 8: Testing of water samples

Plate 9: Comparing tube-well water (left) & filtered water (right)

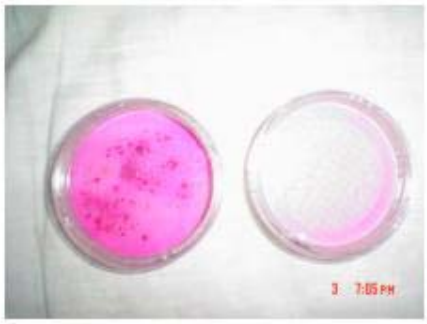


Plate 10: Comparing colonies of tube-well water (left) & filtered water (right)

Plate 11: Materials required for the experiment

Plate 12: Arsenic awareness programme