ARSENIC BIOSAND FILTER:
"STUDY ON THE EFFECT OF AIR SPACE BETWEEN THE RESTING WATER AND THE DIFFUSER BASIN ON ARSENIC REMOVAL AND DETERMINATION OF GENERAL FLOW CURVE" (A case study of Nawalparasi district, Tilakpur V.D.C.)

A Thesis

Submitted for partial fulfillment for the Bachelor Degree in Environmental Science (Honor's Degree) to the department of Biological Science and Environmental Science

School of Science, Kathmandu University

By

Shashank Pandey

Kathmandu University

July 2004

Declaration by student

I, Shashank Pandey, hereby declare that the work presented herein is original work done by me and has not been published or submitted elsewhere for the requirement of a degree programme. Any literature date or work done by other and cited within this thesis has given due acknowledgement and listed in the reference section.

Shashank Pandey

Place: Kathmandu University

Date:

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Date:

Dr. Sanjay Nath Khanal (External Examiner)

(Supervisor)

Associate Professor Department of Biological Sciences and Environmental Science

Dr. Roshan Raj Shrestha

(Supervisor)

ENPHO (Executive Chairman)

Dr. R.B. ChhetriHead, Department of Biological Sciences and Environmental Science

Certificate

Certified that the thesis entitled "STUDY ON THE EFFECT OF AIR SPACE BETWEEN THE RESTING WATER AND THE DIFFUSER BASIN ON ARSENIC REMOVAL AND DETERMINATION OF GENERAL FLOW CURVE" (A case study of Nawalparasi district, Tilakpur V.D.C.) submitted by Mr. Shashank Pandey towards partial fulfillment for the Bachelor's Degree in Environmental Science (Honors degree) is based on the investigation carried out under our guidance. The thesis part therefore has not submitted for the academic award of any other university or institution.

____________________ ____________________

Dr. Sanjay Nath Khanal
(Supervisor)
Associate Professor

Dr.Roshan Raj shrestha
(Supervisor)

Abstract

The study attempt to investigate the effect of air space between the diffuser basin and the resting water level on removal of arsenic by the Arsenic Biosand Filter. In addition, the study focused on the determination of general flow curve for the filter , determination of time required for volume of water to be filtered and also to comprehend the social acceptance of the filter.

Four filters from Tilakpur VDC of Nawalparasi district were selected for the research.. Altogether 150 water samples were collected and flow rate of each sample was taken. The collected samples were tested for arsenic by using ENPHO arsenic field test kit. Besides this, the social acceptance of the filter was evaluated through questionnaire and informal survey.

To accomplish the objective some hypothesis was set. And the result obtained from the research was compared with the hypothesis set. And according to the comparison the result and conclusion were made. And thus the result obtained from the research was not according to the hypothesis set and this thesis describes the different reasons not satisfying the hypothesis

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List of abbreviations

As: Arsenic

AIRP: Arsenic Iron Removal Plant

Bp: Boiling point

BCHIMES: Between Census Household Information Monitoring and Evaluation Centre

BSF: Bio Sand Filter

CBS: Center Bureau of Statistic

Conc.: Concentration

DWSS: Department Of Drinking Water Supply And Sewage

DMAA: Dimethyl Arsenic Acid

ENPHO: Environment and Public Health Organization.

EHC224: Environment Health Criteria 224

GOs: Government Organizations

IARC: International Agency for Research on Cancer.

INGO: International Non Government Organization

L: Liter

MMAA: Monomthyl Arsenic Acid.

Mp.: Melting Point.

MIT: Massachusetts Institute of Technology.

NGO: Non-Government Organization

NRC: National Research Council

NRCS: Nepal Red Cross Society.

NEWAH: Nepal Water for Health.

Ppb. Parts per billion

Ppm.: Parts per billion.

RWSSP: Rural Water Supply and Sanitation Program

RWSSFDB: Rural Water Supply and Sanitation Fund Development Board.

TDI: Tolerable Daily Intake

UNICEF: United Nation Children Fund.

VDC: Village Development Committee.

WHO: World Health Organization.

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CHAPTER 1 HISTORICAL BACKGROUND

Water resource, water supply and water quality in Nepal

Nepal is the 2nd richest country in water resource in the world, possessing about 2.27% of the world water resource (CBS 1999). Despite this fact planned water supply was stated only in the fourth plan (1970-1975). The national coverage of water supply system was only about 4% in 1970. A separate institution, the Department of Drinking Water Supply and Sewerage (DWSS) was established during that period. By the end of water supply and sanitation decade (1990), the coverage substantially increased to 36% of the total population, with the rural population and urban population at 33% and 67% respectively. The recent Between Census Households Information, Monitoring and Evaluation System (BCHIMES) report-2000 indicates water coverage at 78% for rural and 92.3% for the urban population (Shrestha, 2003).

Sanitation facility is very poor condition having only 29% national coverage and issue on water quality has not been given proper attention (Shrestha et.al, 2203). Rural communities continue to use the most convenient source of water irrespective of quality. Regular outbreaks of water borne epidemics and increasing number of patients being admitted to hospitals due to water related diseases indicates that only supplying of drinking water is not sufficient to improve public health status unless continued effort is made both on water supply and sanitation.

Nepal water resources are considerable with surface run-off in the order of 200 km3 annually. In general, there is very little rainfall from November to January. In addition to surface water, Nepal's ground water resources are also extensive.

In Nepal, the guideline value for national drinking water quality standard has been suggested by Pyakural (1994) and Task Force (1995)

Table: 1 Proposed Drinking Water Quality in Nepal

Parameters	Goal	Acceptable
PH	6.5	6.5-9.2
Color (Pt-Cu scale)	15	30
Turbidity (NTU)	5	10
Manganese, Mn (mg/lit)	0.1	0.5
Iron, Fe (mg/lit)	0.3	3
Copper, Cu (mg/lit)	1	5
Chloride, Cl (mg/lit)	250	1000
Arsenic, As (mg/lit)	0.05	-
Cyanide, Cn (mg/lit)	0.07	0.2
Lead, Pb (mg/lit)	0.01	0.1
Mercury, Hg (mg/lit)	0.001	0.002

(Source: ENPHO magazine)

Situation of Arsenic Contamination in Nepal:

Arsenic-contamination in the groundwater of Terai in Nepal is now becoming a new challenge for the nation's water supply sector. According to the arsenic database prepared by the National Arsenic Steering Committee as of November 2003, 7% of the 28956 tubes wells tested so far are found to contain arsenic levels above the national limit of 50 ppb . (Greater than 20% are above WHO limit of 10 ppb). Studies have also indicated that the arsenic distribution is not uniform throughout the country. Many of the villages in Nawalparasi and Rautahat districts and some of the villages in other Terai districts (Bara, Parsa, Siraha, Saptari, Kapilbastu, Rupandehi, Bardiya and Kailali) are found to be highly affected by arsenic (ENPHO Magazine 2004). Continued consumption of arsenic contaminated water generally leads to numerous diseases, including skin cancer, gangrene, hematological poisoning, cardiovascular and nervous disorders. The lungs, genitourinary tract, and other organs may also be affected. There is currently no clinical treatment for arsenic toxicity in the human body other than to stop arsenic intake.

Provision of arsenic free water is the only option to safeguard public health in arsenic affected communities. There are several safe water options like improved dug well, pond water filtration, spring water or deep boring water supply. However, all of these options may be unavailable and unaffordable. In this case, arsenic affected communities should be provided with practical and inexpensive household level treatment options. Different types of arsenic removal techniques have been adapted throughout the world in arsenic-affected communities

Most of these treatment techniques are based on coagulation, precipitation, simple aeration, and adsorption. Treatment through activated alumina, use of coagulants and the three kolshi system with iron filings are some of the most common household-level treatment techniques employed in West Bengal and Bangladesh. In Nepal, the provision of safe drinking water options in arsenic-affected communities is still inadequate. Only a few agencies like the Nepal Red Cross Society (NRCS), Rural Water Supply and Sanitation Support Program (RWSSSP), and Rural Water Supply and Sanitation Fund Development Board (RWSSFDB) have safe water provision programs. However, safe water options are usually only reserved for communities who received tube wells under an agency's program. Therefore many arsenic affected communities are yet unaware of treatment options available. In addition, although household treatment options like Two Gagri Filter (a ferric chloride coagulation and filtration process) and Three Kolshi System (a iron fillings adsorption and filtration process) have been practiced in some communities, these options were found to have several technical and social problems after a few months of operation. The problems include quick clogging, difficulties to supply chemicals regularly, and an increase in microbial contamination in treated water

1.2 Objectives and Limitation of the Study

1.2.1 Objectives

The broad objective was to study about the Arsenic Bio-Sand Filter in the Nawalparasi district, Tikapur Village development committee.

The specific objectives of the study were:

- To examine the effect of Air space between the resting water and diffuser basin in removing the Arsenic from Arsenic Bio-Sand Filter.
- To determine the flow pattern of the filtered water inside Arsenic Bio-Sand Filter.
- To determine time required for a volume of water to be filtered from Arsenic Bio-Sand Filter.
- To study the social acceptance of the Arsenic Bio-Sand Filter.

1.3 Limitation of the study

- All filters from the Tilakpur V.D.C. were not selected because not all filters were in good condition and also due to time and budget limitation.
- In the case of one filter, the time required for the volume of water to be filtered was not taken, because of the time constriction.
- Some water samples could not be analyzed for cross checking due to the budget limitation.

1.4 Hypothesis set to achieve the objective

The objective of the study is **to examine the effect of air space between the resting water and the diffuser basin in removing the arsenic from Arsenic Biosand Filter.**

It is hypothesized that there may be an effect of air space in removing the arsenic from filter. The filter is designed in such a way that there is some air space between the diffuser basin and resting water. The air space in the filter is required to supply Oxygen for the growth of Bio film on the top of sand layer. In the filter, the volume between the resting water level within the filter and the bottom of the diffuser basin is up to 10 L. So the influent water usually passes through the iron nails bed quickly and accumulates in this 10 L space. It is because the resistance to water flow through the iron nails bed is much less than the resistance to water flow through the fine sand layer below. If the space between the sand layer and diffuser basin is reduced, then a greater portion of the incoming water will remain in the diffuser box, instead of accumulating in the space below. This will increase the contact time between the influent water and the iron nails, and may improve arsenic removal (Ngai.T, 2003.).

The periodic fluctuation in arsenic concentration was excepted if the experiment results follow our hypothesis

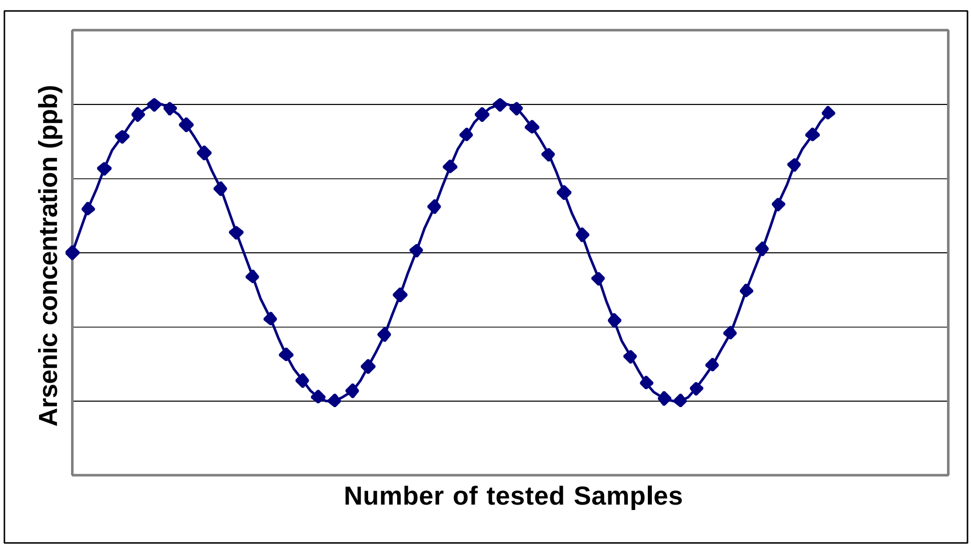


Figure 1: Periodic Fluctuation of Arsenic concentration.

Another objective was **to determine the flow pattern of water inside Arsenic Biosand Filter**.

Darcy's law governs the flow rate of the filter. That is the filter flow rate is proportional to the water level above the outlet pipe. The higher the water level, the higher the hydraulic head, which leads to higher Darcy's flux through the sand, which in turns means higher flow rate (Ngai.T, 2003.)

The imaginary line is drawn according to our hypothesis (Figure..). It is assumed that if the volume of water in the basin is 100%, then the flow rate is maximum (100%) and if there is no any water left in the basin (0%), the flow rate is also 0%

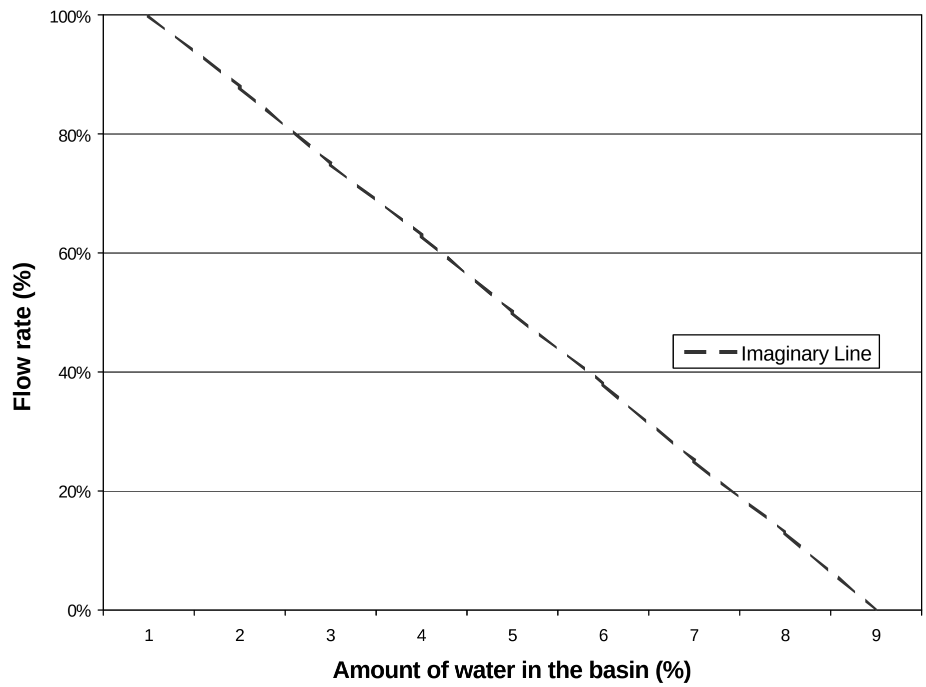


Figure 2: Imaginary line for the flow curves.

CHAPTER 2 LITERATURE RIVIEW

2.1 Chemistry of Arsenic

Arsenic is P-Block, group IV element of the periodic table. It has an atomic number 33 and atomic mass 74.91 with the five electrons in outer most shell. The oxidation state of Arsenic compounds found in the environment is either III or V. The two-electron reduction of arsenate As (V) to arsenite As (III) is favored in acidic solution, where as the reverse is true in basic solution. Arsenic can exist in four valency states -3, 0, +3 and +5. Element arsenic is not soluble in water, under moderately conditions, arsenite (+3) may be the dominant form, but arsenate (+5) is generally the stable oxidation state in oxygenated environment.

Arsenic is stable in dry air, but tarnishes in moist air, giving first a bronze then black tarnish. When heated in air it sublimes at 615?C and forms AS4O6 not AS4O10 but depending upon the oxygen presents (Lee, 1994)

Table 2: Properties of arsenic

Atomic Weight (^{12}C= 12.0000)	74.9216
Mp at 39.1 Mpa (38.6 atm), $^{?}$C	816
Bp, $^{?}$C	615, sublimes
Density at 26$^{?}$C, Kg/m^{3}	5778
Covalent radius	1.21?A
Ionization energy (Kg/mol)	947 (1st) 1950 (2nd) 2732 (3rd)
Latent heat of fusion, J/ (mol K)^{2}	27,740
Latent heat of sublimation,	31,974
Specific heat at 25$^{?}$C, μm/(m$^{?}$C)	5.6
Electrical resistivity at 0$^{?}$C, μ? cm	26
Magnetic susceptibility at 20$^{?}$C, cgs	$-5.5*10^{-6}$
Bond type	Covalent
Crystal system	Hexagonal (rhombohedral)
Pauling’s electronegativity	2.0
Hardness, Mohr’s scale	3.5

(Source: Othmer, 2002; Lee, 1994; EHC224, 2002)

2.2 Sources of Arsenic

Arsenic is the naturally occurring elements in the environment. Arsenic is present in more than 200 mineral species; the most common is arsenic pyrite to be present in the rock (Table-3). It is naturally part of the earth crust. Volcanic action is the most important natural source of arsenic, followed by low temperature volatilization. So depending upon its nature it will be divided in two types; Natural source and anthropogenic source.

Table- 3: Major arsenic minerals occurring in nature

Minerals	Composition	Occurrence
Native arsenic	As	Hydrothermal and veins
Niccolite	NiAs	Vein deposits and norites
Regular	AsS	Vein deposits, often associated with orpiment, clays and lime stones, also deposits from hot springs
Orpiment	As_2S_3	Hydrothermal veins, hot springs, volcanic sublimation product
Cobaltite	CoAsS	High-temperature deposits, metamorphic rocks
Arsenopyrite	FeAsS	The most abundant As mineral, dominantly mineral veins
Tennantite	$(Cu, Fe)_{12}As_4S_{13}$	Hydrothermal veins
Enargite	Cu_3AsS_4	Hydrothermal veins
Arsenolite	As_2O_3	Secondary mineral formed by oxidation of arsenopyrite, native arsenic and other As minerals
Claudetite	As_2O_3	Secondary mineral formed by oxidation of realgar, arsenopyrite and other As minerals
Scorodite	$FeAsO_4.2H_2O$	Secondary Mineral

Annabergite	(Ni, CO)$_3$ $(AsO_4)_2.8H_2O$	Secondary Mineral
Hoernesite	Mg_3 $(AsO_4)_2.8H_2O$	Secondary Mineral, smelter wastes
Haematolite	$(Mn,Mg)_4Al(AsO_4)(OH)_8$	
Conichalcite	$CaCu(AsO_4)(OH)$	Secondary Mineral
Pharmacosiderite	Fe_3 $(AsO_4)_2$ (OH)3.5 H_2O	Oxidation product of arsenopyrite and other As minerals

(Source: EHC224, 2002)

2.2.1 Natural Source

In nature arsenic occurs in variety of minerals (table-3) is the main constituents of more than 200mineral species, of which about 60% are arsenate, 20% sulfide and sulfosalt and the remaining 20% including arsenides, arenites, oxides and elemental arsenic. The most important source is as sulphides occurring as traces in other ores. The common ores are Arsenopyrite (FeAsS), Regular (As_4S_4) and Orpiment (As_2S_3). These last two are found in volcanic areas. Other few elements found in nature are Arsenolite(As_4O_6), Cobalite(CoAsS), White Cobalt ($CoAs_2$), Arsenical Iron (AsFe and As_4Fe_3), Nickel Glance (NiAsS), Kupfernicel (NiAs) and White Arsenic (As_2O_3) (Lee,1994).

2.2.2 Anthropogenic source

There are different arsenic compound, which are produced and used by human. Different arsenic compound produced and used in the industry such as, elementary arsenic, Gallium arsenide, arsenic trioxide etc. Arsenic trioxide, Arsenic pentaoxide, sodium arsenate and arsenite, Potassium arsenate and arsenate, Calcium arsenate are found in insecticides, pesticides, herbicides, fungicides, rodenticidies, wood preservatives, and other uses.

Arsenic released form natural agencies such as weathering processes on a global scale is estimated to be about $8*10^4$ metric tones per year while man made activities account for $24*10^4$ metric tones per year (Dara, 2002).

2.3 Use of arsenic

2.3.1 Industrial uses

Element arsenic is used in alloys with lead storage batteries, manufacturing of glass, semi-conductor and photoconductor, and linoleum and oil cloth and also used in extraction iron from iron ore, Gallium Arsenide (GaAs) is likely to become a significant replacement for silicon in electronic industries also. The hemeselenide of arsenic is also used in glass manufacturing. Arsenic oxide is used as a moderate in textile industries (Dara, 2002).

2.3.2 Pesticides and insecticides uses

- Arsenic trioxide (As_2O_3) is used in rodenticides, insecticides, herbicides as poison in ancient time (Dara, 2002).
- Lead arsenate ($PbHAsO_4$), Sodium arsenate and Calcium arsenate ($Ca_3 (AsO_4)_2$) were used as pesticides and insecticides (Dara, 2002).
- Monosodium arsenate and Dimethyl arsenic acid are specially used as weed killer (Katyal and Stale, 1993).

2.3.3 Wood preservation use

Chromated copper arsenate and fluorochromo arsenate phenyol are used as wood preservatives. Elemental arsenic is incorporated in some copper and lead base alloys to enhance their hardness and thermal resistance (Daran, 2002).

2.3.4 Medical uses

- In the 19^{th} century "folwer's solution", which contains water, As_2O_3, $KHCo_3$ and alcohol was an accepted treatment for leukemia and dermatitis (Lee, 1994).
- Arsenic containing medicine also used in the treatment of skin disorders, Rheumatism, Tuberculosis, Syphilis, Leprosy, Malaria, Asthma, etc. (Bist, 2001) contaminated by

arsenic. There is so much variation in guideline value within different countries and institutes.

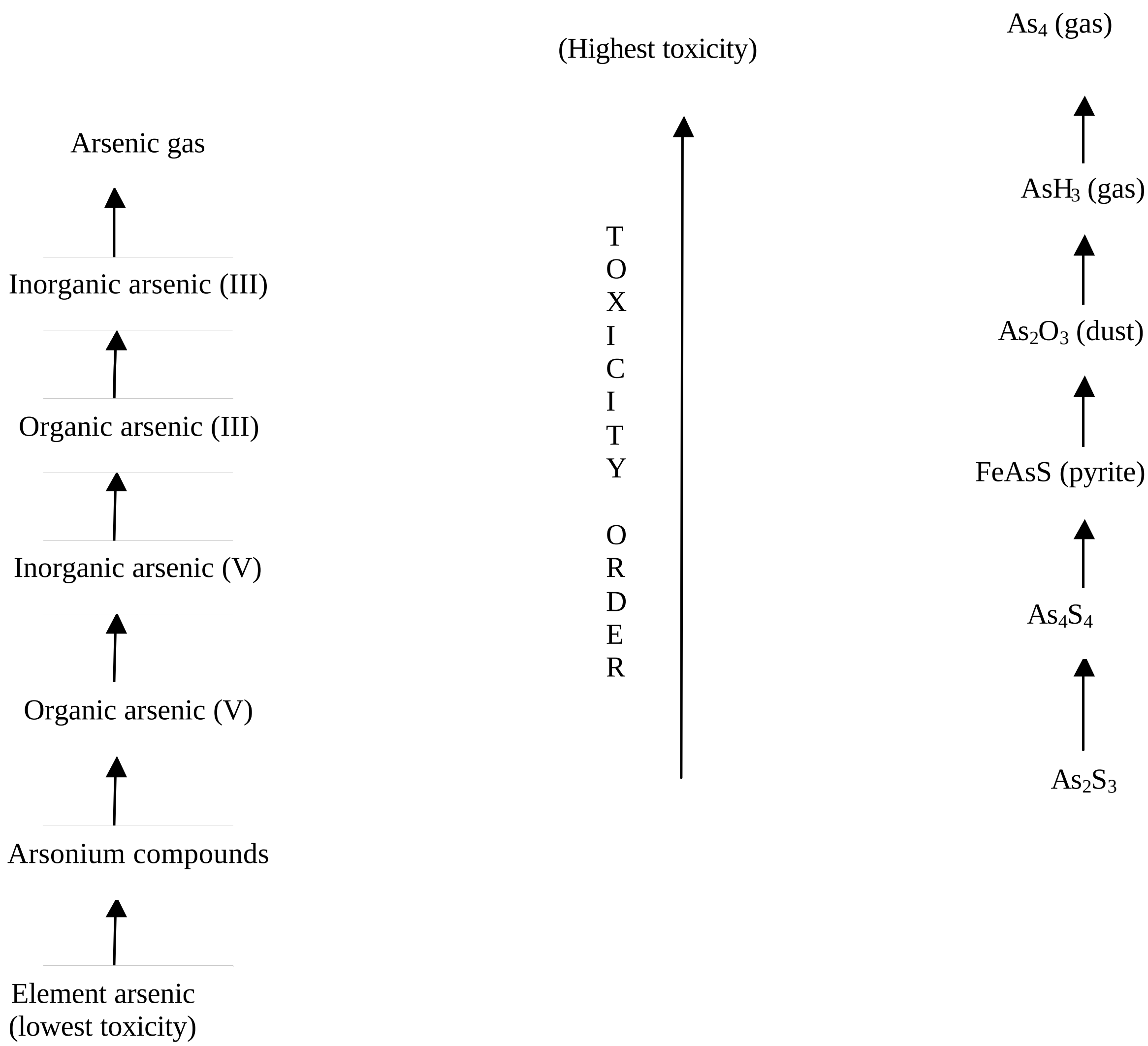
2.4 Guideline value of some countries

Table 4: The national standards of some countries for arsenic in drinking wate

Countries	Standards, µg/L	Countries	Standards, µg/L
Australia (1996)	7	Bangladesh (1997)	50
EU (1998)	10	China	50
Japan (1993)	10	Egypt (1995)	50
Jordan (1991)	10	India	50
Laos (1999)	10	Indonesia (1990)	50
Canada	25	Nepal	50
Mongolia (1998)	10	Philippines (1978)	50
Syria (1994)	10	Srilanka (1983)	50
USA (2001)	10	Viet Nam (1989)	50

(Source: Feroze Ahmed - 2003)

2.5 Toxicity Rank of Arsenic



Figz3: Toxicity Rank

(Source: Lee, 1994)

2.6 Health Effects of Arsenic

Arsenic has been long known as a poison. Even at low concentration, it can produce devastating human health effects. The toxic character of arsenic species mainly depends upon their chemical form. The most toxic form is arsine gas, followed by inorganic trivalent compounds, organic trivalent compounds, inorganic pentavalent compounds, organic pentavalent compounds and elemental arsenic. Both the WHO and EPA have classified inorganic arsenic as a toxin and carcinogen. (Ngai, T 2001)

2.6.1 Route of Entry

Given that arsenic can be found in different environmental media, possible routes of entry include inhalation of arsenic contaminated air, ingestion of arsenic containing food and water, and skin contact. Air borne arsenic concentration is usually between 0.02 and 4 ng/m^3. This concentration is too low to induce any noticeable health effects by inhalation. As for skin contact, arsenic does not readily absorb into skin upon contact. Therefore, inhalation and skin contact are negligible source of entry for arsenic. The ingestion of arsenic containing food and/or water is the most important route of entry. Of the many food categories, fish and shellfish contain the highest level of arsenic. Up to 40 μg of arsenic per gram of dry weight fish can be found. Fortunately, over 90% of the arsenic is in organic form, which is only very mildly toxic. In contrast, for arsenic contaminated drinking water, most of the arsenic is in the more toxic inorganic form. Arsenic levels in groundwater typically average around 1 to 2 μg/L. However, in areas with volcanic rock and sulphide mineral deposits, arsenic levels in excess of 3000 ug/L have been measured. Therefore, arsenic in drinking water is of the most concern.

2.6.2 Acute Toxicity of Arsenic (III) and (V)

Ingestion of large doses of arsenic usually results in symptoms within 30 to 60 minutes, but may be delayed when taken with food. Acute arsenic poisoning usually starts with a metallic or garlic-like taste, burning lips and dysphagia. Then, violent vomiting and hematemesis may occur. These gastrointestinal symptoms are a result of intestinal injury caused by dilatation of splanchnic vessels leading to mucosal vesiculation. After the initial gastrointestinal problems, multi-organ failures may occur, followed by death. Survivors of acute arsenic poisoning commonly incur damage to their peripheral nervous system.

Arsenic (III) and (V) behaves differently in acute poisoning. Arsenic (III) binds and inactivates sulfhydryl-containing enzymes necessary for proper body functions. On the other hand, arsenic (V) elicits toxicity by mimicking phosphate and interfering with ATP production in the mitochondria.

Acute poisoning has a mortality rate of 50-75% and death usually occurs within 48 hours. A lethal does will vary with the arsenic form, but 0.2-0.3 g of arsenic trioxide is usually fatal for adult humans. Reported arsenic (V) LD_{50} values in rats are 110 mg/kg, while the LD_{50} values in rats for arsenic (III) varies from 15 mg/kg to 110 mg/kg. Therefore, arsenic (III) is a magnitude more acutely toxic than arsenic (V). However, in the context of drinking water supply, acute poisoning is less common than chronic exposure.

2.6.3 Chronic Toxicity of Arsenic (III) and (V)

Chronic exposure to low level of arsenic has long since been linked to adverse health effects in human. There are contradictory beliefs on the relative chronic toxicity of arsenic (III) and (V). On one hand, arsenic (III) should be more toxic than (V), as an extension of acute toxicity data. On the other hand, some believe that chronic toxicity at low arsenic levels, as found in most groundwater, is influenced only by total arsenic concentration, not speciation. No matter which hypothesis is correct, long-term exposure to arsenic has proven to cause dermal, vascular, and cancer effects.

2.6.3.1 Dermal

Initially, chronic exposure to arsenic causes skin changes such as hyperpigmentation and keratosis. Hyperpigmentation is an alteration in color resulting in spots on the skin and keratosis is a hardening of skin bulges, usually found in palms and soles. Following hyperkeratosis and hyperpigmentation, cancer may occur. After 10 years of exposure, cancer of the skin may develop. Figure shows a keratosis victim. Recent studies from West Bengal, India and Bangladesh in populations showed that that the age-adjusted prevalence of keratosis rose from zero in the lowest exposure level (< 50 μg/L) to 8.3 per 100 women drinking water containing > 800 μg/L. For men, the age-adjusted prevalence rates rose from 0.2 per 100 in the lowest exposure category to 10.7 per 100 in the high exposure group. For hyperpigmentation prevalence, similar results were reported.

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Figure 4: A Keratosis Victim

2.6.3.2 Vascular Effects

Exposure to arsenic has been linked to various vascular diseases affecting both the large (cardio-vascular) and small blood vessels (peripheral vascular). Blackfoot disease (BFD) in parts of Taiwan is an example of peripheral vascular disease. BFD is characterized by coldness and numbness in the feet, followed by ulceration, black discoloration and subsequently dry gangrene of the affected parts. In addition many of the BDF-patients have shown significantly higher death rate from cardio-vasuclar problems.

2.6.3.3 Cancer

In additional to skin cancer, arsenic exposure in drinking water causes lung, bladder and kidney cancer may appear after 20 years or more years. Studies have consistently shown high mortality risks from lung, bladder and kidney cancers among populations exposed to arsenic via drinking water. Moreover, the risk of cancer for these sites increases with increasing exposure.

2.6.4 Characteristics of Arsenicosis

The disease caused by arsenic is known as arsenicosis. The characteristic of arsenicosis study in different stages (Bist, 2000; Shrestha and Maskey, 2001) which are as follows:

Pre-clinical stage: Not-detectable by clinical manifestation.

↓

Initial stage:

- Skin color becomes black - Melanosis
- The skin becomes rough and though (particularly palms & soles of food) - Keratosis
- Eyes becomes red - Conjunctivitis
- Pain in inhaling – Bronchitis
- Vomiting and Diarrhea – Gastroenteritis

↓

Middle stage:

- Black and white spots on the skin – Leukomelanosise
- Palms and soles are affected by hard nodules – Hyperkeratosis
- Swelling of legs – No pitting odema
- Peripheral neuropathy – Terminal neurosis
- Complications of Kidney and liver

↓

Last stage:

- Infection of lateral organs – Gangrene
- Cancer in lungs, kidneys, uterus and other parts
- Total liver and kidney damage
- Ulcer
- Diabetes and hypertension

Figure 5: Stage of Arsenocis

2.7 Situation of Arsenic in Nepal

Ground water arsenic problem in Nepal is a relatively new issue. This aspect of water quality was considered only in 1999 when WHO/DWSS conducted a small survey in Terai region of Nepal. It was followed by a mass scale arsenic contamination investigation by Nepal Red Cross Society (NRCS) with the technical assistance of Environmental and public Health Organization (ENPHO) and financial assistance of Japanese Red Cross Society. Later other rural water supply agencies like RWSSP, NEWAH and Development of Water Supply and Sewerage (DWSS/UNICEF) started testing its tubewells in its project areas of Terai region. In total out of the 20,240 tubewells tested till date in Nepal, 1550 (about 8%) tubewells has arsenic concentration above Nepal Interim Standard (50 µg/L) while 5881 (29%) tubewells exceeds the WHO standards. It is estimated from these studies that about 3.19 million people may have been affected by arsenic contamination in Nepal (Maskey, 2003). The work summarized in the following table:

Table 5: Arsenic Level at Different Districts in Nepal as of November 2003

		Samples with Arsenic Concentrations					Percentage exceeding	
S. No.	Districts	0- 10 ppb	11 to 50 ppb	> 50 ppb	Total no. of tests	Max. Conc. detected ppb	10 ppb	50 ppb
1	Illam	4	0	0	4		0	0
2	Jhapa	493	77	1	571	79	14	0
3	Morang	339	260	4	603	70	44	1
4	Sunsari	646	241	4	891	75	27	0
5	Saptari	669	94	9	772	98	13	1
6	Siraha	245	235	104	584	90	58	18
7	Udaypur	3	0	0	3	5	0	0
8	Dhanusa	425	64	13	502	140	15	3
9	Mahhotari	177	21	4	202	80	12	2
10	Sarlahi	402	114	16	532	98	24	3
11	Rautahat	814	2289	262	3365	324	76	8
12	Bara	1983	550	51	2584	254	23	2
13	Parsa	1895	253	59	2207	456	14	3
14	Kathamndu	35	20	1	56	141	38	2
15	Chitwan	219	0	0	219	8	0	0
16	Nawalparasi	1385	1340	1108	3833	571	64	29
17	Rupandehi	2191	410	124	2725	2620	20	5
18	Kapilbastu	3471	466	162	4099	589	15	4
19	Palpa	26	0	0	26		0	0
20	Dang	639	25	3	667	81	4	0
21	Banke	2673	645	42	3360	270	20	1
22	Bardiya	472	160	20	652	181	28	3
23	Kailali	149	106	44	299	213	50	15
24	Kanchanpur	167	21	12	200	221	17	6
Total		19522	7391	2043	28956			
Total %		67%	26%	7%	100%			

Source: (National Arsenic Steering Committee, Nepal.)

2.8 Introduction to Different Types of Arsenic Removal Technology

Arsenic is relatively a new issue in Nepal compared to other drinking water problems. However, the magnitude of this problem in the public health is felt by ENPHO has learned from the experiences of the neighboring arsenic affected countries like Bangladesh and India and produced different types of household different types of household and community arsenic removal filters which are distributed to the arsenic affected households of Nepal. Three types of household arsenic removal filters and one community leval arsenic removal system are now in practice (ENPHO,2004).

I) Two Gagri system and II) Three Gagri III) Arsenic Bio- sand Filter

2.8.1 Two Gagri System

This is simple and effective household device promoted by ENPHO 2001, which can remove more than 90% of arsenic and can also kill pathogen. In this method coagulation, oxidation, co-precipitation followed by filtration occurs to remove arsenic from water. In this filter, a black colored arsenic removal powder is used, which is a specially prepared mixture of coagulant, activated carbon and oxidizing agent for removing arsenic from the water. A packet of arsenic removal powder can be used for purifying 20 liters of water. Agencies working in arsenic have been providing this filter to the arsenic affected community in Terai region.

2.8.2 Three Gagri System

The three Gagri systems promoted by ENPHO have a simple design and can be easily assembled by community. This system does not use any chemicals for arsenic removal but uses locally available material like sand, brick and charcoal. The natural filtration process removes arsenic, iron and other unnecessary chemicals. This filter is widely used in the arsenic affected areas of Terai region.

2.8.3 Arsenic Bio-Sand Filter

Massachusetts Institute of technology (MIT),in collbration with ENPHO has developed the Arsenic bio-sand filter, a modified version of the conventional bio-sand that was developed by Dr Manz of the university of callagary.. This filter has been introduced in the Terai region previously for removal of iron and bacteriological contamination. Since this filter system is durable and considering the iron removal efficiency, it is expected that it will also remove arsenic with some modifications. This system removes iron arsenic as well as bacterial contamination without using any chemicals. This filter was introduced at the end of 2002 and is provided to few communities as pilot phase in Terai.

2.9 Arsenic Biosand Filter (ABF)

2.9.1 Background

Passing water through sand is recognized as the single most effective method of water purification. Beginning in the early 1800s, sand beds were used in Europe to treat cholera-infected waters. Passing water through the sand beds experienced a dramatic reduction in cholera. According to WHO," No other single treatment process can effect such an improvement in the physical, chemical, and bacteriological quality of normal surface waters as that accomplished by biological (slow sand) filtration." Based on the principle of slow sand filtration, Dr. David Manz of the University of Calgary, Canada developed a household-scale sand filter called Bio Sand Filter (BSF). Several research and health institutions and NGOs in Canada, Vietnam, Brazil, Nicaragua, Bangladesh and other countries have tested the efficiency of BSF. Several research studies revealed that the removal rate of fecal coliforms from the drinking water is very good (more than 90%) (Ngai.T,2003).

The Arsenic bio sand filter is version of the BSF, which is modified to include Arsenic removal capability.

2.9.2 Arsenic Bio Sand Filter Design

Arsenic Bio Sand Filter comprises two removal units: the arsenic removal unit and the pathogen removal unit. The arsenic removal unit is consisted of plastic diffuser basin, iron nails and some brick chips. The pathogen removal unit is consisted of sand and gravel layers. Cross section of Improved Bio Sand Filter is shown in fig;

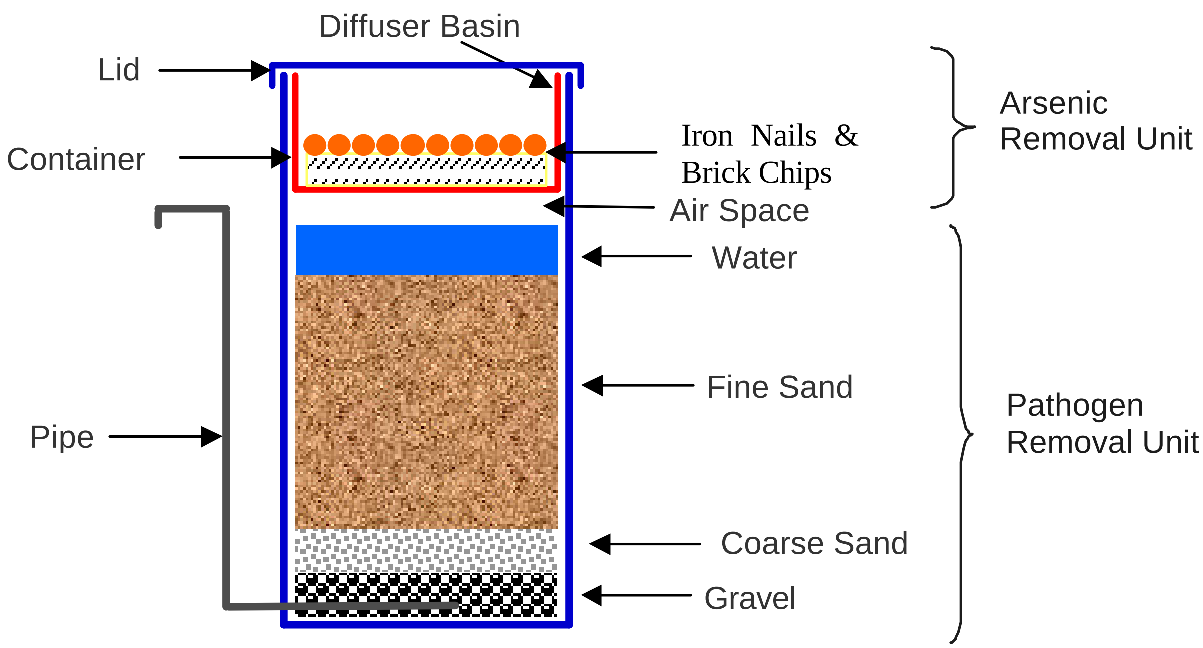


Figure 6: Cross section of Arsenic Biosand Filter. Source: (Ngai T, 2004 presentation.)

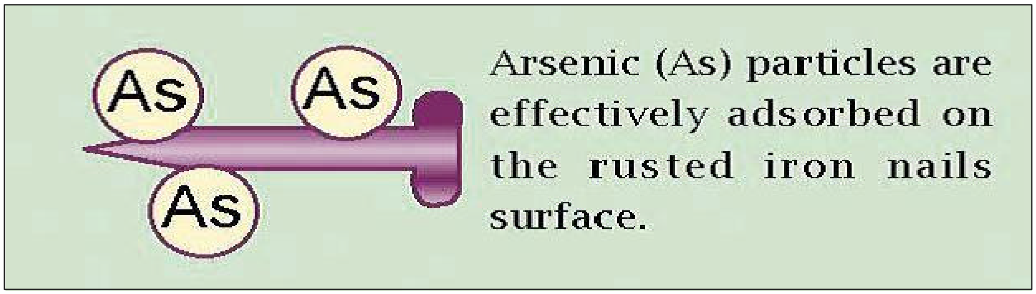
2.9.3 Arsenic Removal

Many of the technologies for arsenic removal rely on few basic chemical processes. They are:

- Oxidation/Reduction
- Precipitation
- Adsorption

In adsorption process, arsenic is strongly attracted to sorption sites on the surfaces of the solid materials like iron and aluminum hydroxide flocs and is effectively removed from the solution by subsequent physical filtration. Arsenic removal technology of ArsenicBio Sand Filter is based upon the adsorption process as it consists of iron nails, which is found to be an excellent adsorbent for Arsenic.

In Arsenic Bio Sand Filter, the iron nails are exposed to air and water, and are rust quickly, producing ferric hydroxide particles. When arsenic contaminated water is poured into the filter, arsenic is quickly adsorbed onto the surface of the ferric hydroxide particles. These arsenic loaded ferric hydroxide particles are trapped on top of the fine sand layer. Most of the arsenic is



already adsorbed on to the ferric hydroxide, and almost all ferric hydroxide is trapped on the top of fine sand layer, as a result, arsenic is effectively removed from the water. Figure illustrates the arsenic removal mechanism arsenic removal mechanism.

Figure 7 : Arsenic Removal mechanism. Source: Ngai T, 2004.

During the process of arsenic removal, iron dissolved in water is also removed through co-precipitation and filtration process.

2.9.4 Pathogen Removal

The pathogen in the Arsenic Biosand Filter can be removed by two mechanisms: physical-chemical and biological.

2.9.4.1 Physical-Chemical Mechanism

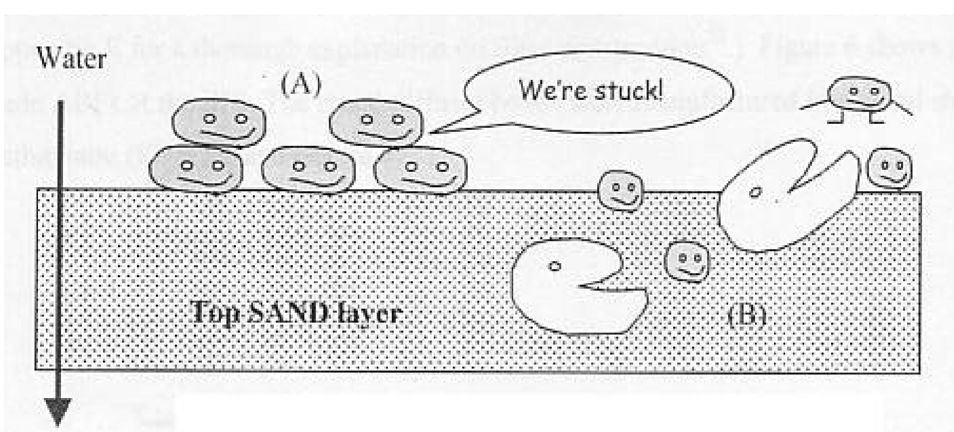
When water passes through the sand bed, many foreign particles are trapped on the top, as the particles are too large to pass through the bed. A tightly packed bed of the sand grains can detain particles about 5% of the grain diameter. For instance, sand with a diameter of 0.1 mm will catch particles that are 5 µm or larger. This is extensively larger than many particles to be removed from surface water such as cysts (1-20µm). Viruses are much less than 1 µm, so must be removed by other means, such as biological mechanisms.

2.9.4.2 Biological Mechanisms

This is the unseen process occurring in a sand bed, which refers its effectiveness in purifying water. When water is passed through the sand bed, the particles it contains-large and small-collide with individual grains of sand. Once a particle encounters a grain of sand, it stays attached. Water that requires filtration usually contains various kinds of organic matter, including living organisms. These particles and organisms accumulate in the uppermost layers of a sand bed, since this is where most of the collision takes place, and eventually develop into a dense biological population, which is known as the biological layer of biofilm. The biofilm consists of threadlike algae, and many other organisms including plankton, protozoa and bacteria. The biofilm needs stability, continuous water environment, diffuser level and basic nutrients, such as organic matter and oxygen. Proper oxygen supply is critical to the biofilm's growth and efficiency. The ABF and BSF are designed in such a way that there is always about 5 cm of resting water above the fine sand layer. The 5 cm resting water level is the optimum heights as at this height the biology surviving in the biofilm receives maximum oxygen. Moreover, this resting water level serves a constant aquatic environment necessary for the organisms present in the layer to survive. The water should not be allowed to flow freely or directly on to the sand as it disturbs the biofilm, which may results incapability of pathogen removal. To protect the biofilm from this disturbance, water should be always poured through the diffuser basin.

When microbiologically contaminated water is poured into the filter, predatory organisms present in the biofilm layer will consume the incoming pathogens. In addition, the biological population in the biofilm produces substances toxic to intestinal bacteria. Many studies and experiments reveal that this process can be a significant cause of bacterial removal in slow sand filters..

Figure 8. Pathogens Removal Mechanism.



2.9.5 Treatment Efficiency of Arsenic Bio Sand Filter

There are more than 1000 units of Arsenic Bio Sand Filters distributed in the different arsenic affected areas (ENPHO Magazine 2004). An one-year technical monitoring of the filter revealed that the removal rate of the filter for Arsenic, Iron and pathogens is very good.

The average arsenic removal efficiency of the filter is 93% (Ngai T, 2003), which is very good as compare to the other existing arsenic removal technologies. After the filtration, water with arsenic concentration of 450 ppb dropped to 20 ppb, which is quite remarkable. The iron removal efficiency of the filter is also very good (about 99%).

2.9.6 Installation Procedure

The materials needed for installation process are:

- Clean Fine Sand (less than 1mm)
- Clean Coarse Sand (3-6mm)
- Clean Gravel (6mm-15mm)
- Plastic Diffuser Basin
- 5 kg Iron Shoe Nails
- A plastic bio sand filter with a lid
- Some brick chips
- Bleaching powder or Chlorine Solution (Piyush)

? Flush a filter with water to remove dirt, mud.

? Place the filter inside a home in a secure area.

? Pour gravel into the bottom of the filter to a depth of 5 cm (2in.) and level.

? Add water to the filter so that the gravel is covered with 10 cm (4in.) of water.

? Slowly add coarse sand into the water to a depth of 5 cm (2in.) above gravel. Level the sand surface by hand.

? Slowly add fine sand, making sure that the sand is added water. The fine sand should be added until its top surface is 5 cm (2in.) below the water when the water starts to drain from the filter. This will be about 46 cm (18in.) of the sand.

? Place the diffuser basin inside the filter and add 5 kg of iron nails. The diffuser basin must not be touching the surface of the water at resting level.

? Add some brick chips on the top of the nails.

? Flush the filter with water until the water runs clear.

? Place the lid on the filter.

The filter is now ready to use.

Note:

- Before the installation of the filter, sand, coarse sand and gravel must be carefully washed and disinfected by chlorine solution (piyush).
- During the installation, always add sand to water.
- The larger grain size of fine sand, more the flow rate and vice versa. Thus, the porosity of the fine sand must be balanced somewhere in the middle. It means the porosity should be small enough to trap particles in the water and large enough to let the water through and allow some room for biological growth.

2.9.7 Operation Procedures

The operation procedure of the filter is very simple. Before the use of the filter, the iron nails at the diffuser basin should be checked so as to ensure that the nail surface is always flat. If the surface is not flat, the basin is taken out and shaken to evenly distribute the iron nails. Then the basin is placed to the filter and slowly water is poured into the basin. Water should be poured through the brick chips so that the iron nails could not be dispersed while pouring water. The filtered water can be collected from the out let.

Note:

- Never pour water directly onto the sand layer. Always place diffuser basin before pouring water.
- The filter lid should be closed at all time, except when pouring water into the filter.

- It needs two or three weeks to develop the biological layer inside the filter so that to reach optimum removal of bacteria, viruses and protozoa. Thus, during that period, the filtered water can be disinfected using chlorine solution (Piyush).
- Water should be poured through the filter consistently (at least once every two days).
- Children should be discouraged from playing with filter or investigating the filter.
- Always store filtered water in a clean, sealed container.

2.9.8 Maintenance Procedure

The flow rate is the only maintenance indicator for the filter. If the flow rate through the filter decrease to an unacceptable rate (a trickle that cannot meet household needs), it is time to maintain the filter. First, the filter lid and plastic basin containing the iron nails are removed. Then the top 2 cm of the sand are gently scraped by hands. As a result of this scraping, the water that sits above the sand will become very turbid. Then remove that turbid water using a small container. Replace the diffuser basin and slowly add water to replace the water that was just removed. The scraping and water removal procedure is repeated at least 3 times. Finally the plastic basin containing the iron nails is shaken to make sure that the iron nails cover the whole surface of the basin and then put back into the filter. Replace the lid, now the filter is clean and can be use immediately.(ENPHO magazine)

CHAPTER 3 MATERIAL AND METHOD

3.1 Study Area Description

The study area cover the village of Nawalparasi district lies in Lumbini zone, southern part of western Development region of Nepal. The study was conducted at Tilakpur V.D.C., Magarmuda tole, ward no. 8. Most of the people of these areas are extracting underground water through shallow tube wells for drinking purpose.

3.2 Secondary Data Collection

3.2.1 Official document and literature survey

Different NGO's, INGOS and GOS are working on the arsenic contamination of ground water in terai region of Nepal. Their research work and report become helpful for this study. Reports from ENPHO on Arsenic Biosand filter were collected for this research study. Different books, magazine related to Arsenic and its removal technologies were also used for the literature review.

3.2.2 Expert Suggestion and discussion

Expert and research suggestion and discussion were helpful for this research study. On the time of my research study I met few researcher and expert during research on Arsenic Biosand filter and discuss with them.

- Suggestion of Mr. Tommy Ka Kit Ngai (MIT), Lecturer/ Resarch at MIT who is currently working with ENPHO and was helpful for the research site selection and method of data collection.
- Suggestion of Mr. Bipin Dangol, Environmental Engineer, ENPHO was helpful for the data analysis, and also during the result and discussion of the study.

3.3 Primary data collection

The primary data collection for the research was done at the time of field study.

3.3.1 Selection of sampling site

The site selected for the research was at Nawalparasi district, Tilakpur V.D.C., Magarmoda tole, ward no. 8. Here, most of the people use tube wells for drinking water. And the Arsenic concentration in the tube wells was 250 ppb. And for the safe drinking of water the villagers use Arsenic Biosand filter.

3.3.2 Number of filter selected for the research

There were about 25 filters distributed to the villager. But due to lack of time and considering the condition of filter, total 4 filters were selected and those filter selected were in good condition and currently in use.

3.3.3 Material used during sample collection

After the filter were selected, there were different material used for the sample collection. The materials are as follows:

1 Liter Mug

This mug was used to measure the filtered water, the mug was filled 2 times so that 2 liter of water was collected and after 2 liter of filtered water collected flow rate was measured.

20 liter bucket

This bucket was used for the collection of exactly 20 liter of water from the tube well for the research.

100ml of graduated cylinder

The graduated cylinder was used to measure the flow rater of filtered water (i.e. sec/100).

Sampling bottles

Sampling bottles were used to collect the filtered water sample.

Stop watch

The watch was used to measure the time required to fill 100 ml of graduated cylinder.

Arsenic Test Kit

In the field arsenic concentration of ground water was measured by ENPHO-Arsenic test kit, developed by ENPHO, It is a color indicator test. The principle reaction of test includes, "the contents of arsenic in the water are converted to arsine gas by the reaction of Sodium Borohydride in acidic medium. The arsine gas is produce yellow to brown stain on the mercury (II) bromide paper. The concentration of arsenic in the sample is determined by the comparison of the intensity of the stain with the color chart."

Content of the arsenic field test kit

1.	Arsenic generator flask	1 piece
2.	Mercury bromide paper holder	2 pieces
3.	Measuring cylinder	1 piece
4.	Forceps	2 pieces
5.	Absorbent cotton	1 piece
6.	Disposal bag	2 pieces
7.	Color chart	1 piece
8.	Tablet 1	1 bottle
9.	Tablet 2	2 bottles

10. Mercury bromide paper 1 bottle
11. Standards solution (5000 µg/L) 1 bottle
12. Reagent I 1 bottle

Procedure for field test kit:

1. A piece of cotton was taken with help of forceps and insert in the wide part of the mercury bromide paper holder tube.
2. The insert cotton was socked by the one drop of reagent I.
3. Cap of mercury bromide holder tube was opened and a piece of mercury bromide holder was placed with the help of forceps in that cap and was fit in the tube.
4. 20 ml of water sample was measured and poured in arsenic generator flask.
5. A piece of tablet 1 was added in water sample in generator flask.
6. A piece of tablet 2 was added in water sample and immediately fit the wide part (the cotton inserted part) of the mercury bromide paper holder tightly in Arsine generator flask and was allowed to stay for complete dissolve.
7. After complete dissolve the tablets, the flask was gently swirled and kept that standing for five minutes.
8. The mercury bromide paper holder was detached from the flask.
9. The cap of the holder was detached from the mercury bromide paper holder and the filter paper was removed fro the cap with the help of forceps.
10. The color stained on the bromide paper was compared with the color provided in the kit.
11. The observed value was tabulated.

3.3.4 Method used for collecting the sample

At first the selection of filter was done. There were four Arsenic Biosand filter selected for the sample collection, which were currently in use for drinking purpose. After the selection of filter following procedure was applied for the sample collection.

- At first the tube well water was collected in the 20 liter bucket and the water was poured into the filter.
- The 20 L of water collected from the Arsenic Biosand filter was discarded.
- After this again, 20 liter of tube well water was collected in the bucket and poured into the filter, and the samples were taken for each 2-liter of filtered water. The flow rate of each sample was also measured.
- The samples were collected for four phases to get enough data for analysis

The samples were then tested for arsenic concentration by using ENPHO Arsenic Test Kit. The influent water of each phases were also tested.

CHAPTER 4 RESULT AND DISCUSSION

Table 6: Identification of four Filters

Arsenic Biosand Filter Number	Contact Person
ABF 1	Bishow Nath Chaudhary
ABF 2	Sher Bahadur Chaudhary
ABF 3	Gorakh Chaudhary
ABF 4	Som Nath Chaudhary

4.1 The effect of air space between the resting water and diffuser plate in removing the arsenic from Arsenic Biosand Filter:

ABF 1

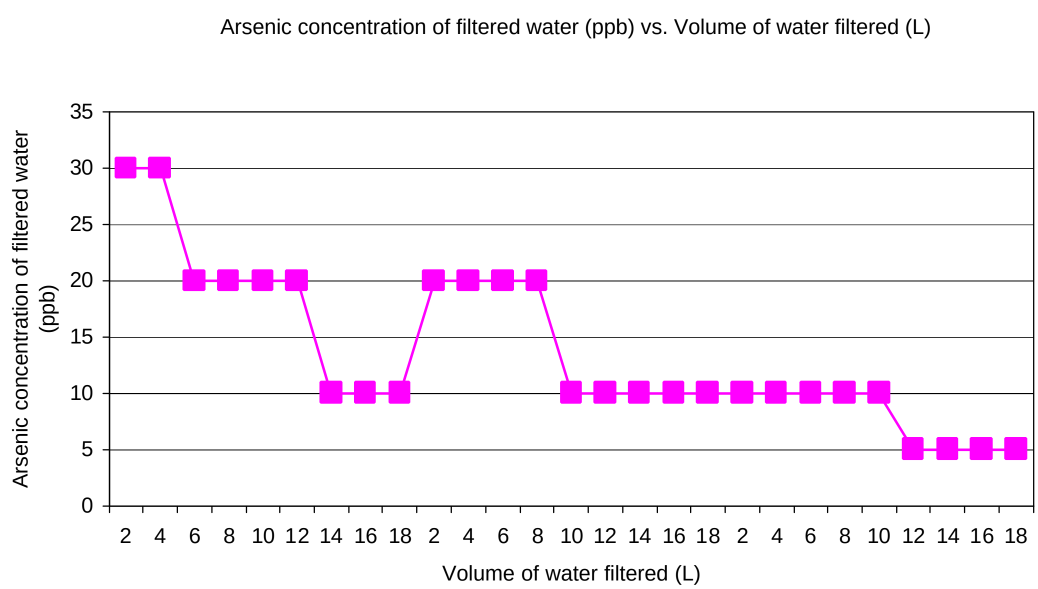


Figure 9: ABF 1 Arsenic concentration of filtered water (ppb) vs. Volume of Water filtered (L)

The data obtained from an experiment performed at ABF 1 match with our hypothesis. The periodic fluctuation in arsenic concentration after each phase was observed in the graph. This shows that the air space effects in the removal of arsenic.

ABF 2

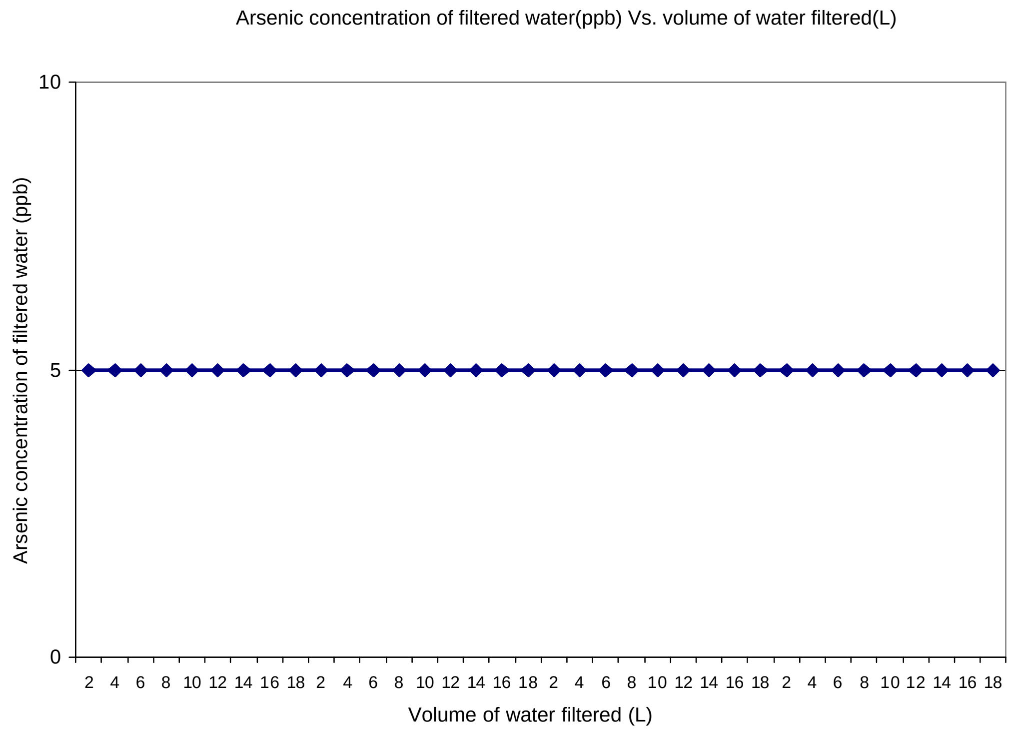


Figure 10: ABF 2 Arsenic concentration of filtered water (ppb) vs. Volume of filtered water

The data obtained from the experiment performed at ABF 2 does not match with the hypothesis. No any periodic fluctuation in arsenic concentration was observed. The arsenic concentration of each effluent water is 5 ppb.

ABF 3

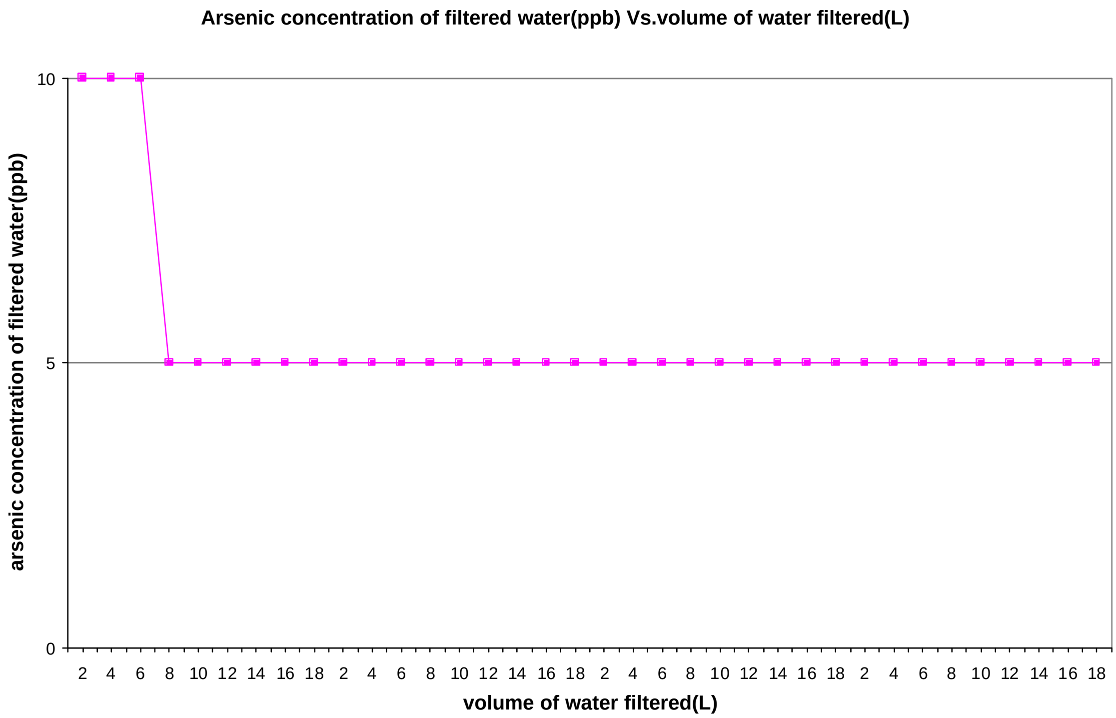


Figure 11: ABF 3 Arsenic concentration of filtered water (ppb) vs. Volume of filtered water

The data obtained from the experiment performed at ABF 3 does not match with the hypothesis. The two initial effluent water samples were found 10 ppb of arsenic concentration, but rest of the results were 5 ppb. Hence no fluctuation in arsenic concentration was observed.

ABF 4

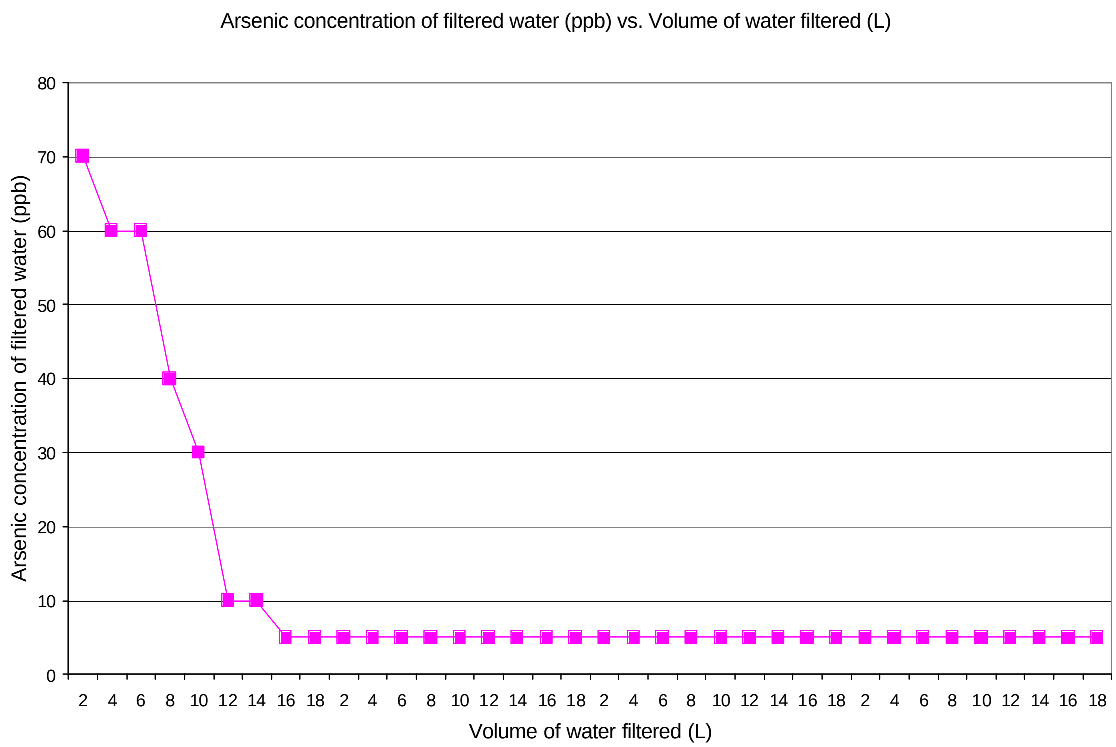


Figure 12: ABF 4Arsenic concentration of filtered water (ppb) vs. Volume of filtered water

The graph of ABF 4 showed that initially there was some fluctuation in arsenic concentration. But after phase 1, all the tested results of effluent water are 5 ppb. Thus no any fluctuation in arsenic concentration

Overall Discussion:

Among the four ABFs, only ABF 1 shows fluctuation in arsenic concentration. Whereas ABF 2 don't show any fluctuation, arsenic is reduced to 5 ppb in each tested samples. In ABF 3, the initial three samples show 10 ppb of arsenic concentration while rest of the samples are 5 ppb of arsenic concentration. The graph of ABF 4 shows there is high arsenic concentration (> 50 ppb) in first three samples and the concentration of arsenic gradually reduces.

So only ABF 1 satisfies our hypothesis, as there is periodic fluctuation in arsenic concentration. Rest of the three ABFs don't show any periodic fluctuation in arsenic concentration. Thus, the result obtained does not show there is any effect of air space in removal of arsenic.

4.2 The flow pattern of water inside arsenic biosand filter

ABF 1

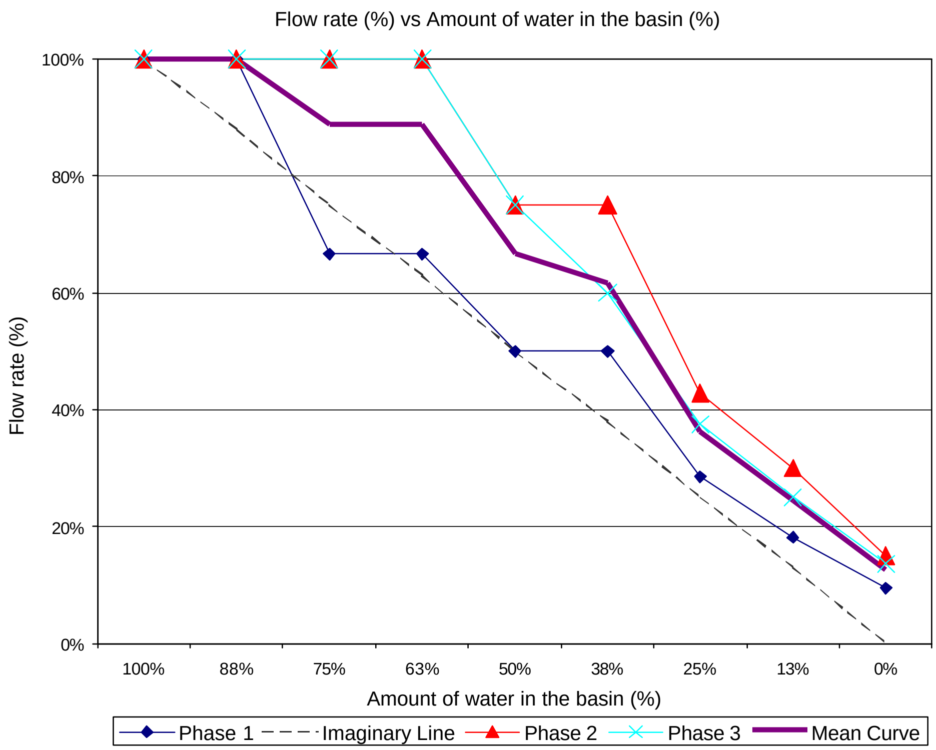


Figure 13: ABF 1 Flow rate (%) vs Amount of water in the basin(%)

. The data obtained from the experiment performed at ABF 1 shows that the phase 1 flow rate curve is close to our imaginary line. Other flow rate curves do not match with the imaginary line.

ABF 2

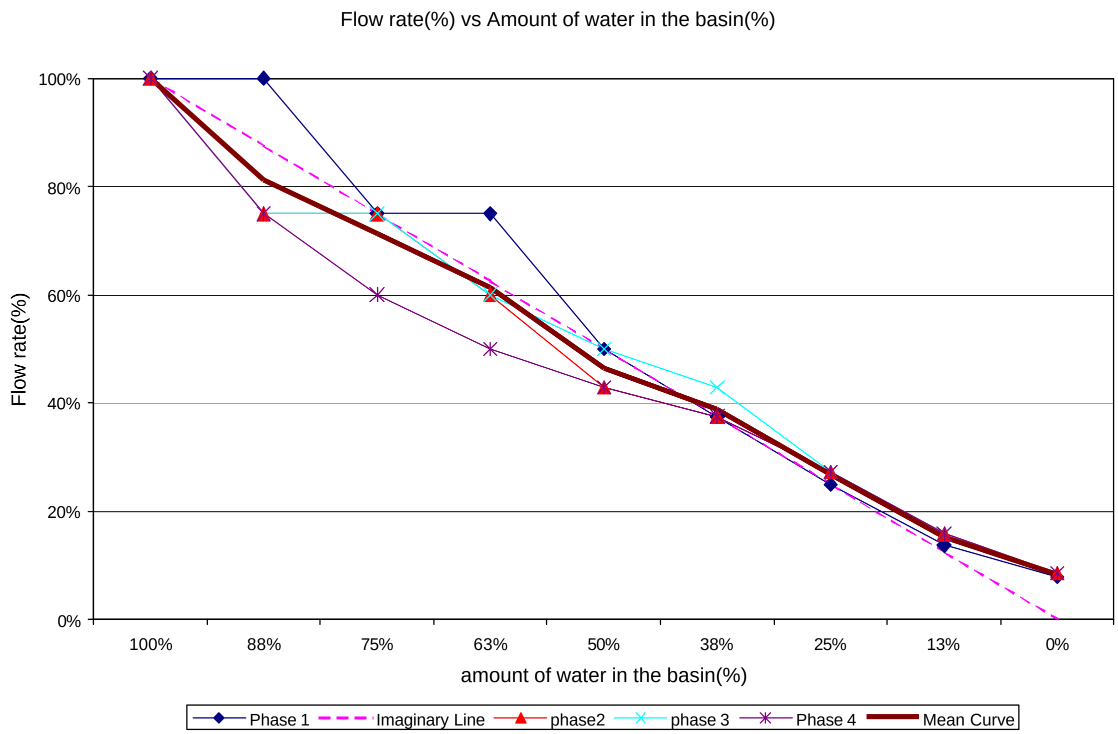


Figure 14: ABF 2 Flow rate (%) vs Amount of water in the basin(%)

In the case of ABF 2, the mean curve is very closer to the imaginary line. When the amount of water in the basin is greater than 50%, then all the curves follow the imaginary line. That means whenever the amount of water in the basin is more than 50%, the flow rate is stable.

ABF 3

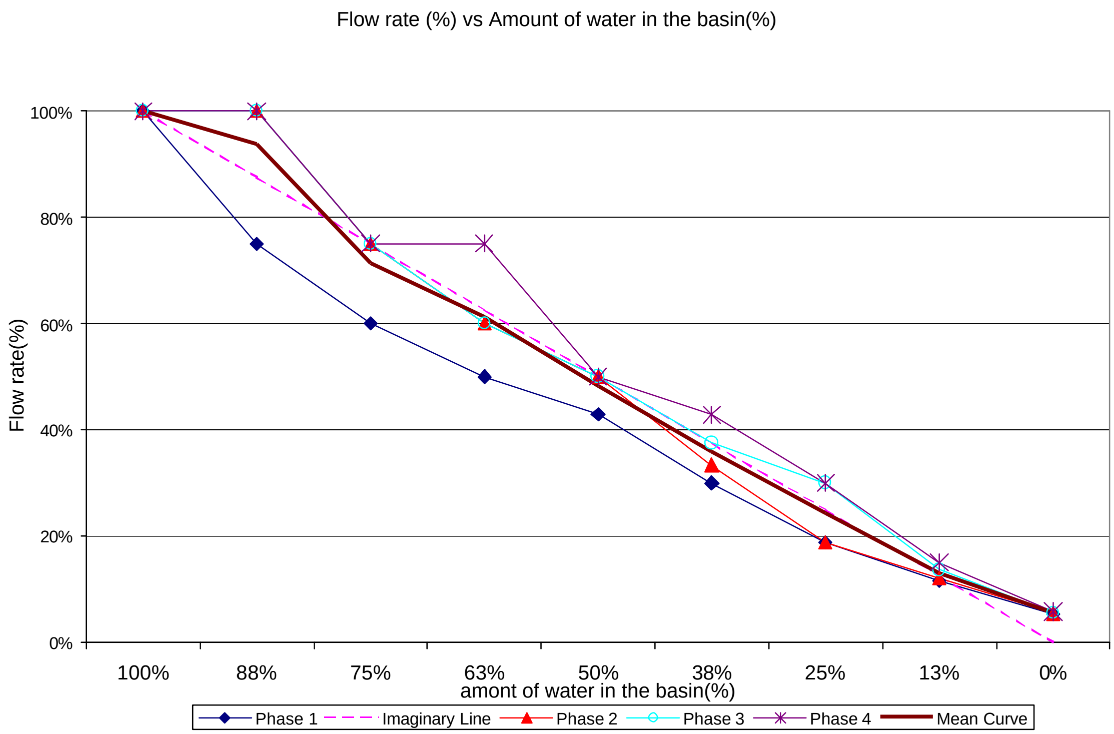


Figure 15: ABF 3 Flow rate (%) vs Amount of water in the basin(%)

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In ABF 3, phase 1 and phase 4 curves show inconsistency. While mean curve is very close to imaginary line, which shows that it, follows our hypothesis.

ABF 4

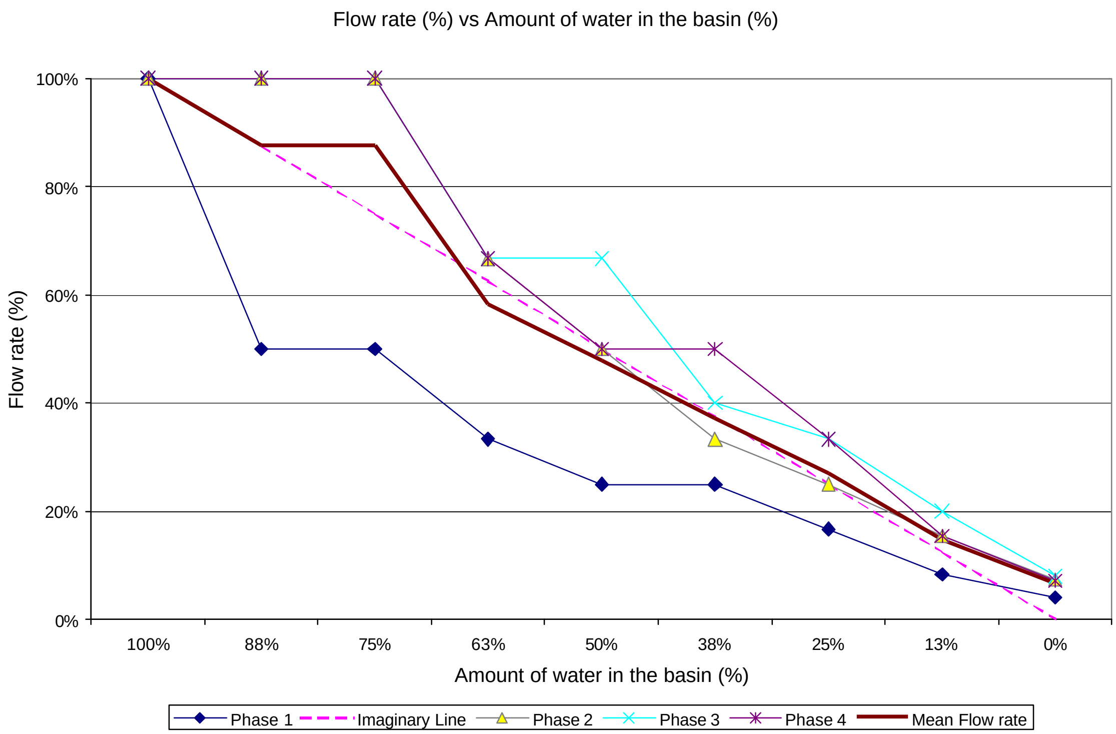

Figure 16: ABF 4 Flow rate (%) vs Amount of water in the basin(%)

For ABF 4, none of the curves follow the imaginary line. This means the filter has not constant flow rate with regard to the amount of water in the basin.

4.3 To determine the time required for the volume of water to be filtered from arsenic biosand filter

ABF 2

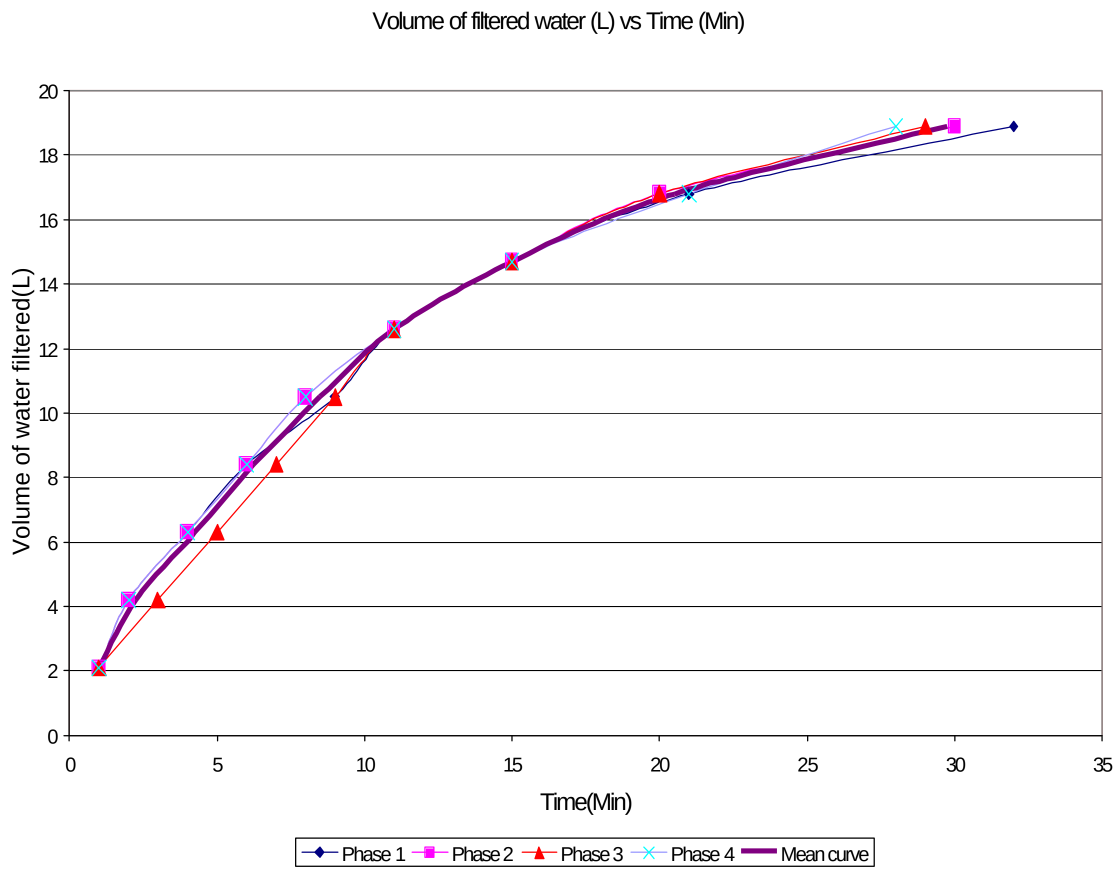

Figure 17: ABF 2 Volume of filtered water (L) vs Time (min)

The data obtained for the ABF 2 shows the time required to fill each volume of water filtered is equal for all phases.

ABF 3

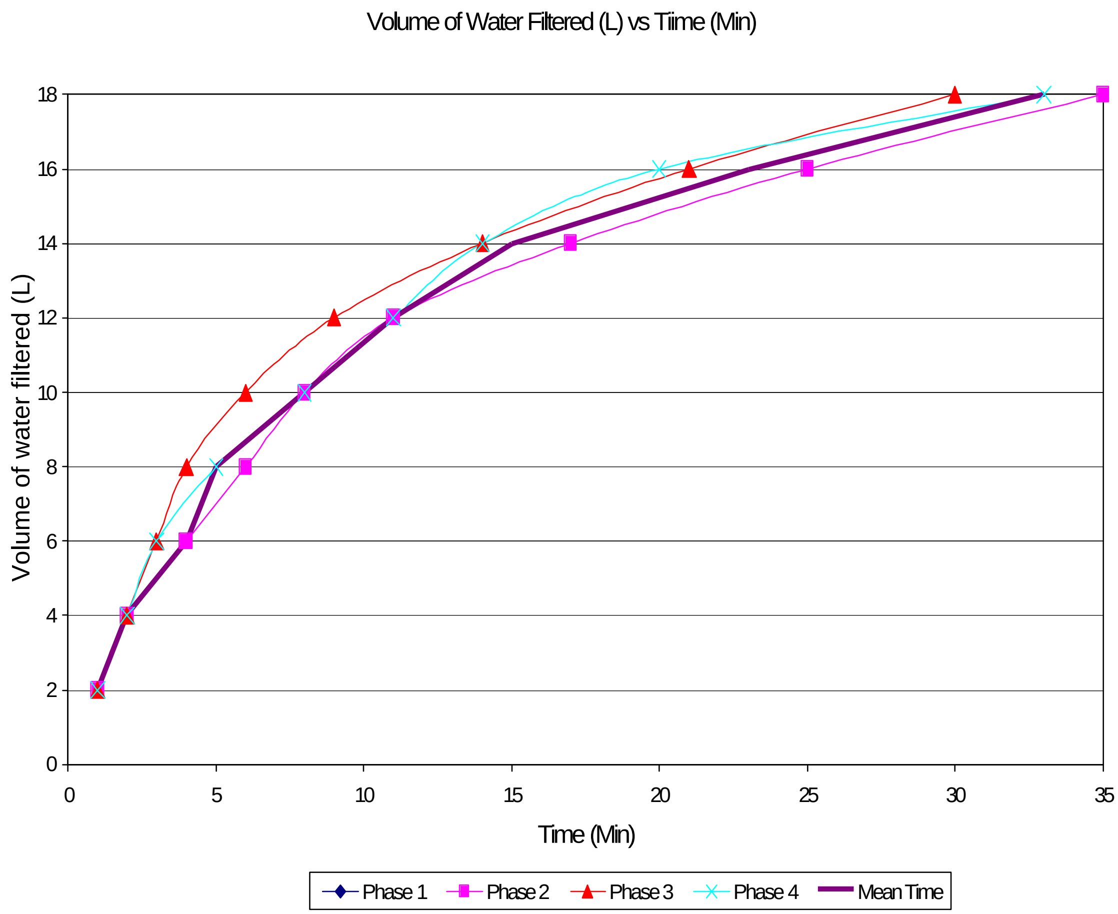

Figure 18: ABF 3 Volume of filtered water (L) vs Time (min)

The data obtained for the ABF 2 shows the time required to fill each volume of water filtered is equal for all phases.

ABF 4

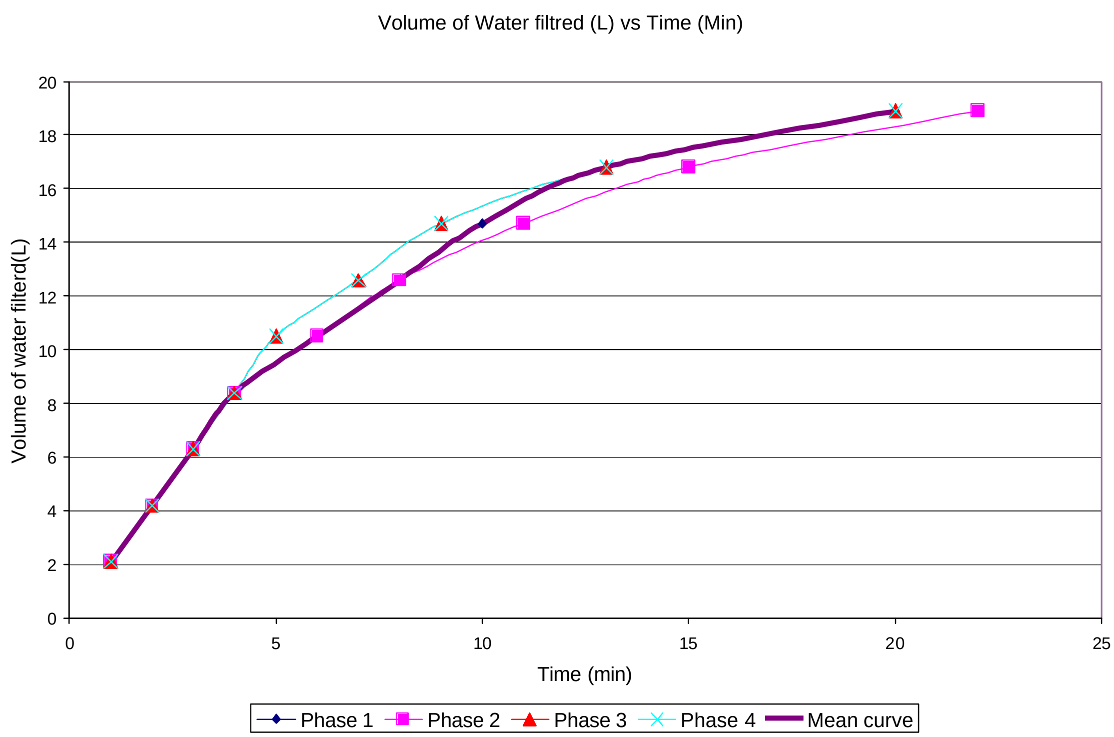

Figure 19: ABF 4 Volume of filtered water (L) vs Time (min)

In the case of ABF 4 four initial samples for every phase show the same time required to fill same volume of water filtered. Afterwards, phase 2 and phase 4 curves show different time required to fill filtered water with compare to other curves.

4.4 The social acceptance of the filter

To study the social acceptance of the filter there were some general questionnaire asked to the users.

According to the general questionnaire asked to the users in Magarmuda Tole, Panchanagar VDC, it was found that there were 25 users of Arsenic Biosand filter. These users were very much happy with the performance of Arsenic Biosand filter.

The users like high filtration rate, simple operation and minimal maintenance. They also like the filters' ability to remove color (iron), foul taste and odor (organic substance H_2S), producing aesthetically pleasing water (Ngai.T 20003). They also think the filter is durable and permanent drinking water solution. It was also found that due to the filter capacity to produce pure water the user said that they found the water taste good for cooking.

According to the questionnaire asked it was found that the people living in this Tole are aware of disease caused by drinking arsenic contaminated water. They are now ready to pay for the filter. It was found that at first when filter was distributed for free in that Tole by Nepal Red Cross Society, the people thought that it was useless, but now they are ready to pay for the filter. From this fact it can be seen that the acceptance of filter is increasing.

CHAPTER 5 CONCLUSION

- The result obtained by the study does not support the hypothesis. The result obtained does not show there is any effect of air space in the removal of Arsenic.
- If there were significant effect, there would have been a similar representation of hypothetical curve.
- It is concluded that the reason for not getting the Hypothetical curve may be due to following reasons:
    - After the water is passed from the diffuser plate the water carry iron rust along with it and gets collected on the top sand layer. This rusted particle acts as adsorbing material for arsenic removal.
- The flow pattern of the filtered water displays it comply with the imaginary line. Thus, the flow rate is directly proportional to the amount of water in the basin.
- From the results and graphs, the time required to collect the filtered water can be estimated. But the data obtained is applicable only for 20 liter of filtered water.
- The users of the filters are very happy to have the filter. They like high filtration rate, simple operation and minimal maintenance.

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CHAPTER 6 RECCOMENDATION

- It is recommended that for the good result of the filter, users need to have good information about the filter.
- The information about the filter can be disseminated by different medias, for example newspapers, pamphlets, radio, etc.
- More awareness campaign should be launched to make aware of arsenic and its mitigation measures. More monitoring is needed to know the regular arsenic removal performance of the filter.
- To enhance the good flow rate, the filter should be checked and cleaned when it is required.
- The filter should not be cleaned very frequently, because, it takes time to develop the bio film in the water level which acts as a main factor for reducing pathogens in the water.
- For the efficient arsenic removal the nails present in the diffuser plate must be rusted.
- The nails should not be taken out from the diffuser plate for cleaning purpose.
- There should be brick chips present above the nails to reduce the direct impact of water, which may cause the hole in the diffuser plate displacing the iron nails.
- The filter should be always kept in upright position.
- There should not be any modification of the filter, like putting the tap on the outlet, which causes water logging in the filter.
- More study is needed to determine the actual effect of air space in the arsenic removal. It is suggested to decrease the air space between the resting water level and diffuser basin of the present design, and to perform the comparative study on the effect of air space in arsenic removal of present and new filter design.

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ANNEX A

Defining the terms used during the sample collection:

1. **Volume of water filtered (L):**_This term denote that this amount of water was filtered through ABF.
2. **Amount of water in the filter (%):** This term denote that this amount of water is present in diffuser basin. A value of 100% means the diffuser is full of water. A value of 0%means the diffuser has no water.

And this was calculated in terms of percentage by assuming that at first the water is poured into the filter, so the filter is full of water and it can be said that the filter is 100% full of water. And after the total water is filtered it reaches to 0%.

Since, 100% = 12.5

= 100-12.5

= 87.5 ~ 88%

3. **Flow rate (sec/100ml):** This term denote that this many seconds were taken to fill 100 ml of graduated cylinder.
4. **Liter per hour:** The data obtain i.e. (sec/100ml) was converted to lit/hour.

2 sec ?   100 ml

1 sec ?   100 ml/2

1 hr (3600 sec) ?   100/2 * 3600/100 = 180 liter

(1000 ml = 1 liter)

5. **Flow rate (%):** The flow rate was also converted to percentage by following method. At first the filter is full of water and the flow rate is also high so at first we assume 100% flow rate. as the flow rate (in terms of L/hr)decreases, the flow rate(in terms of %) also decreases. In other words, the % flow rate is the flow rate normalized according to normal flow rate.

$$180/120 = 100/x$$

$$x = 100/1.5 = 67\%$$

6. **Mean flow rate (%):** The mean flow rate (%) of all phase was also calculated by adding the flow rate (%) of each phase and dividing by the total number of phase.
7. **Time required for volume of water to be filtered (min):** This is the time that is required for certain volume of water to be filtered.
8. **Mean time required for volume of water to be filtered (min):** The mean time required for volume of water to be filtered was calculated by adding all the total time required for volume of water to be filtered for each phase and dividing by the total number of phase.

Arsenic concentration of filtered water (ppb): This data defines the As concentration in the filtered water

ANNEX B Table Of Data Obtained During The field Study

Bishow Nath Chaudhary (20 liters. water used)

Raw samples: 250 ppb(before filtration)
Phase 1:
After filtration:

Volume of water filtered (L)	Amount of water in the basin (%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	Mean flow rate (%)	Arsenic conc. of filtered water(ppb)
2	100%	2	180	100%	100%	30
4	88%	2	180	100%	100%	30
6	75%	3	120	67%	89%	20
8	63%	3	120	67%	89%	20
10	50%	4	90	50%	67%	20
12	38%	4	90	50%	62%	20
14	25%	7	51	29%	36%	10
16	13%	11	33	18%	24%	10
18	0%	21	17	10%	13%	10

Raw samples: 250 ppb (before filtration)
Phase 2:
After filtration:

Volume of water filtered (L)	Amount of water in the basin (%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	Arsenic conc. of filtered water(ppb)
2	100%	3	120	100%	20
4	88%	3	120	100%	20
6	75%	3	120	100%	20
8	63%	3	120	100%	20
10	50%	4	90	75%	10
12	38%	4	90	75%	10
14	25%	7	51	43%	10
16	13%	10	36	30%	10
18	0%	20	18	15%	10

Raw Water: 250 ppb (before filtration)
Phase 3:
After filtration:

Volume of water filtered (L)	Amount of water in the basin (%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	Arsenic conc. of filtered water(ppb)
2	100%	3	120	100%	10
4	88%	3	120	100%	10
6	75%	3	120	100%	10
8	63%	3	120	100%	10
10	50%	4	90	75%	10
12	38%	5	72	60%	5
14	25%	8	45	38%	5
16	13%	12	30	25%	5
18	0%	22	16	14%	5

Note : Sample collected every after 2 liters of water.

Sher Bahadur Chaudhary (20 liters. water used)

Raw samples: 250 ppb (before filtration)
Phase 1:
After filtration:

Volume of water filtered (L)	Amount of water in the basin (%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of (%)	Mean flow rate (%)	Time required for volume of water to be filtered (Min)	Mean Time required for volume of water to be filtered (Min)	Arsenic conc. of filtered water (ppb)
2	100%	3	120	100%	100%	1	1	5
4	88%	3	120	100%	81%	2	2	5
6	75%	4	90	75%	71%	4	4	5
8	63%	4	90	75%	61%	6	6	5
10	50%	6	60	50%	46%	9	9	5
12	38%	8	45	38%	39%	11	11	5
14	25%	12	30	25%	27%	15	15	5
16	13%	22	16	14%	15%	21	21	5
18	0%	38	9	8%	8%	32	30	5

Raw samples: 250 ppb (before filtration)
Phase 2:
After filtration:

Volume of water filtered (L)	Amount of water in the basin (%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	Time required for volume of water to be filtered (Min)	Arsenic conc. of filtered water(ppb)
2	100%	3	120	100%	1	5
4	88%	4	90	75%	2	5
6	75%	4	90	75%	4	5
8	63%	5	72	60%	6	5
10	50%	7	51	43%	8	5
12	38%	8	45	38%	11	5
14	25%	11	33	27%	15	5
16	13%	19	19	16%	20	5
18	0%	35	10	9%	30	5

Raw samples: 250 ppb (before filtration)
Phase 3:
After filtration:

Volume of water filtered (L)	Amount of water in the basin (%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	Time required for volume of water to be filtered (Min)	Arsenic conc. of filtered water(ppb)
2	100%	3	120	100%	1	5
4	88%	4	90	75%	3	5
6	75%	4	90	75%	5	5
8	63%	5	72	60%	7	5
10	50%	6	60	50%	9	5
12	38%	7	51	43%	11	5
14	25%	11	33	27%	15	5
16	13%	19	19	16%	20	5
18	0%	35	10	9%	29	5

Raw samples: 250 ppb (before filtration)
Phase 4:
After filtration:

Volume of water filtered (L)	Amount of water in the basin(%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	Time required for volume of water to be filtered (Min)	Arsenic conc. of filtered water(ppb)
2	100%	3	120	100%	1	5
4	88%	4	90	75%	2	5
6	75%	5	72	60%	4	5
8	63%	6	60	50%	6	5
10	50%	7	51	43%	8	5
12	38%	8	45	38%	11	5
14	25%	11	33	27%	15	5
16	13%	19	19	16%	21	5
18	0%	35	10	9%	28	5

note : Sample collected every after 2 liters of water.

Gorakh Chaudhary (20 liters water used)

Phase 1:
Raw samples: 250 ppb (before filtration)
After filtration:

Volume of water filtered (L)	amount of water in the basin %	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	mean flow rate (%)	Time required for volume of water to be filtered (Min)	Mean Time required for volume of water to be filtered (Min)	Arsenic Conc. of filtered water (ppb)
2	100%	3	120	100%	100%	1	1	10
4	88%	4	90	75%	94%	3	2	10
6	75%	5	72	60%	71%	4	4	10
8	63%	6	60	50%	61%	6	6	5
10	50%	7	51	43%	48%	8	8	5
12	38%	10	36	30%	36%	11	11	5
14	25%	16	23	19%	24%	16	16	5
16	13%	26	14	12%	13%	24	23	5
18	0%	57	6	5%	6%	35	33	5

Phase 2:
Raw samples: 250 ppb (before filtration)
After filtration:

Volume of water filtered (L)	amount of water in the basin (%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	Time required for volume of water to be filtered (Min)	Arsenic conc. of filtered water(ppb)
2	100%	3	120	100%	1	5
4	88%	3	120	100%	2	5
6	75%	4	90	75%	4	5
8	63%	5	72	60%	6	5
10	50%	6	60	50%	8	5
12	38%	9	40	33%	11	5
14	25%	16	23	19%	17	5
16	13%	25	14	12%	25	5
18	0%	55	7	5%	35	5

Phase 3:
Raw samples: 250 ppb (before filtration)
After filtration:

Volume of water filtered (L)	Amount of water in the basin (%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	Time required for volume of water to be filtered (Min)	Arsenic conc. of filtered water(ppb)
2	100%	3	120	100%	1	5
4	88%	3	120	100%	2	5
6	75%	4	90	75%	3	5
8	63%	5	72	60%	5	5
10	50%	6	60	50%	7	5
12	38%	8	45	38%	10	5
14	25%	10	36	30%	15	5
16	13%	22	16	14%	22	5
18	0%	54	7	6%	28	5

Phase 4:
Raw samples: 250 ppb (before filtration)
After filtration:

Volume of water filtered (L)	Amount of water in the basin(%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	Time required for volume of water to be filtered (Min)	Arsenic conc. of filtered water(ppb)
2	100%	3	120	100%	1	5
4	88%	3	120	100%	2	5
6	75%	4	90	75%	3	5
8	63%	4	90	75%	5	5
10	50%	6	60	50%	8	5
12	38%	7	51	43%	11	5
14	25%	10	36	30%	14	5
16	13%	20	18	15%	20	5
18	0%	52	7	6%	33	5

Note : Sample collected every after 2 liters of water.

Som Nath Thakur (20 liters. water used)

Raw samples: 250 ppb (before filtration)
Phase 1:
After filtration:

Volume of water filtered (L)	Amount of water in the basin (%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	Mean flow rate (%)	Time required for volume of water to be filtered (Min)	Mean time required for volume of water to be filtered (Min)	Arsenic conc. of filtered water (ppb)
2	100%	1	360	100%	100%	1	1	70
4	88%	2	180	50%	88%	2	2	60
6	75%	2	180	50%	88%	3	3	60
8	63%	3	120	33%	58%	4	4	40
10	50%	4	90	25%	48%	6	6	30
12	38%	4	90	25%	37%	8	8	10
14	25%	6	60	17%	27%	10	10	10
16	13%	12	30	8%	15%	13	13	5
18	0%	25	14	4%	7%	20	20	5

Raw samples: 250 ppb (before filtration)
Phase 2:
After filtration:

Volume of water filtered (L)	Amount of water in the basin (%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	Time required for volume of water to be filtered (Min)	Arsenic conc. of filtered water(ppb)
2	100%	2	180	100%	1	5
4	88%	2	180	100%	2	5
6	75%	2	180	100%	3	5
8	63%	3	120	67%	4	5
10	50%	4	90	50%	6	5
12	38%	6	60	33%	8	5
14	25%	8	45	25%	11	5
16	13%	13	28	15%	15	5
18	0%	27	13	7%	22	5

Raw samples: 250 ppb (before filtration)
Phase 3:
After filtration:

Volume of water filtered (L)	Amount of water in the basin (%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	Time required for volume of water to be filtered (Min)	Arsenic conc. of filtered water(ppb)
2	100%	2	180	100%	1	5
4	88%	2	180	100%	2	5
6	75%	2	180	100%	3	5
8	63%	3	120	67%	4	5
10	50%	3	120	67%	5	5
12	38%	5	72	40%	7	5
14	25%	6	60	33%	9	5
16	13%	10	36	20%	11	5
18	0%	25	14	8%	18	5

Raw samples: 250 ppb (before filtration)
Phase 4:
After filtration:

Volume of water filtered (L)	Amount of water in the basin (%)	Flow Rate (sec per 100 ml)	liter per hour	Flow rate in terms of %	Time required for volume of water to be filtered (Min)	Arsenic conc. of filtered water(ppb)
2	100%	2	180	100%	1	5
4	88%	2	180	100%	2	5
6	75%	2	180	100%	3	5
8	63%	3	120	67%	4	5
10	50%	4	90	50%	5	5
12	38%	4	90	50%	7	5
14	25%	6	60	33%	9	5
16	13%	13	28	15%	13	5
18	0%	28	13	7%	20	5

Note : Sample collected every after 2 liters of water.

ANNEX C Photographs

Filtered Water Sample Collection.

Tube well Water Sample Collection.

ENPHO Arsenic Field Test Kit

20 Liter bucket, 1 Liter Mug and 100 ML Measuring Cylinder.

Arsenic testing by using ENPHO Test Kit.

Tommy Ngai explaining about the Study Methodology.