TECHNICAL AND SOCIAL EVALUATION OF THREE ARSENIC-REMOVAL TECHNOLOGIES IN NEPAL

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Abstract

The Terai region of Nepal suffers from arsenic contamination of its groundwater supplies. For the past three years, the Massachusetts Institute of Technology Nepal Water Project Master of Engineering teams have traveled to Nepal to research the extent of the arsenic contamination and to test various household treatment options to remediate it. In January 2003, the author traveled to Nepal as part of this year's Nepal Water Project to study the viability of three arsenic removal technologies: The Arsenic-Biosand filter, the Three-Kolshi and the Two-Kolshi. This study consists of a technical and social evaluation of these three technologies. All three of the filters work well at the technical level, as they were all found to have very high arsenic-removal rates. Considering that arsenic was discovered in Nepal recently (2001) compared to other regions such as West Bengal (1983) or Bangladesh (1981), this study found that there was a relative high level of arsenic awareness within the affected population.

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1.0 INTRODUCTION

1.1 MIT NEPAL WATER PROJECT

Twenty-five Massachusetts Institute of Technology Department of Civil and Environmental Engineering Masters of Engineering students have completed or are engaged in current 2002-2003 academic year thesis projects in Nepal. Most of these projects addressed the provision of safe drinking water to the Nepali population and were done in collaboration with the Nepali government, various NGO's on the ground or sometimes independently. Since the creation of the MIT Nepal Water Project in 1999, teams have investigated the viability of implementing various water treatment filters, disinfection options, as well as analyzed and documented the water quality of various drinking water sources such as wells and river.

During the academic year 2002-2003, seven M.Eng candidates along with two students from the Sloan School of Management traveled to Nepal under the auspices of the MIT Nepal Water Project. Four students worked on projects addressing drinking water problems, and the last three worked on wastewater projects in Kathmandu. This group effort culminated in the production of a comprehensive group report summarizing the work done during the academic year. In addition each member wrote an individual thesis that described in great detail his or her project and results.

Figure 1: 2002-2003 Nepal Group

1.2 MIT ARSENIC PROJECTS

As part of the MIT Nepal Project, various students, over the years have worked on projects addressing the groundwater arsenic contamination in this country. In 2000 Patricia Halsey collaborated with the Nepali Department of Water Supply and Sewerage and the Japan/Nepal Red Cross to do for the first time a series of arsenic tests in Nepal. They found that 18 % of the tubewell samples taken in the Terai region were over the WHO guideline value of 10 µg/L (Murcott, 2002). The discovery of arsenic in Nepal can be retraced to this joint effort. In 2001 Jessica Hurd studied the viability of three arsenic-removal technologies in Nepal: Three-Gagri System, the Jerry Can System and the Arsenic Treatment Unit (ATU) made by Apyron Technologies, Inc. In 2002, Soon Kyu Hwang studied the Two-Kolshi system, Barika Poole studied arsenic removal through iron oxide coated sand and Tommy Ngai conducted arsenic speciation tests in various wells in the Terai. After he graduated, Tommy Ngai went on to design his own arsenic removal technology: The Arsenic-Biosand filter (ABF). He won the Lemelson International prize for his design, which allowed him to go back to Nepal on two separate occasions to implement and monitor 10 ABF units in arsenic-affected households.

1.3 OVERVIEW OF NEPAL

Landlocked between India and China, the Kingdom of Nepal covers 147,181 square kilometers. Within this small area, it can be divided into 3 geographic entities: the flat Terai in the south, the Himalayas in the north and the central hills between them. The population is just over 23,000,000, forty percent of whom are under 14. The highly varied terrain has spawned an astonishing array of cultures and societies: 60 according to the Nepalese census and over 100 according to ethnologists (Bista, 1991). The largest groups can be divided as follows on the basis of geographical locations by altitude:

- Himalayas: Sherpas, Dolpa People, Larke and Siar People, Manang Bas, La Pas of Mustang, Olungchung People, Thudam, Topke Gola and Lhomis.
- Central Hills: Brahman and Chetris, Kirati, Newars, Tamangs, Magars, Gurungs and Thakalis.
- Terai: Brahman and Rajputs, Tharus, Rajbansis, Satars and Masalmans. (Nepal's People and Ethnic Groups, 2003)

The religious distribution in Nepal can be summarized as follows: Hindu 90%; Buddhist 5%; Muslim 3%; Kirat 1.7%; Christian 0.2%; other 0.3% (Reed, 2002). These statistics are somewhat misleading as the boundary between religions is blurry in Nepal. Most Nepalese combine Hinduism with Buddhist or shamanistic beliefs. The Buddha is widely believed to be one to the various incarnations of Shiva, a main Hindu deity.

Figure 2: Map of Nepal

According to the World Bank, Nepal is currently the seventh poorest nation in the World with a Gross National Income per Capita of $250 (World Bank, 2001). The widespread poverty and the government's inability to remedy it have ignited a Maoist rebellion in the western part of the country. The rebellion has almost killed Nepal's main source of income, tourism, and is now contributing to the further impoverishment of the country. Nepal has currently on of the most appalling health statistics in the World:

- Life expectancy is 58 years, as compared to 77 years in the United States (World Bank, 2001).
- Estimates of infant mortality are 79 per 1000 births; over ten times the American rate of 5 per 1000 (World Bank, 2001).
- 11% of children die before the age of five (UNICEF, 2001).
- The access to safe drinking water is of 81% (UNDP, 2001).
- The access to adequate sanitation is of 27 % (UNDP, 2001).

1.4 RESEARCH OBJECTIVES

The project undertaken by the author will build on the various arsenic studies completed by the MIT Nepal Water Project. Three types of arsenic removal technologies are currently being studied in Nepal by various NGO's to determine if any of them can be distributed to the population as a final solution to the arsenic problem. These filters have been tested extensively over the years by various NGOs as well as the MIT Nepal Water Project. However, no comprehensive social acceptability study has been done so far of these three filters. This study will be the first to try to evaluate the social acceptability of the three currently available types of arsenic removal filters. In order to achieve that objective, it will try to answer the following two questions:

- What is the level of arsenic awareness of the affected population?
- What is the social acceptability of each of the three types of filters?

With the interest of making this study as complete as possible, it will also try to evaluate the technical performance of the filters, namely their arsenic removal rates and flow rates.

2.0 ARSENIC BACKGROUND

2.1 ARSENIC CHEMISTRY

Arsenic is a naturally occurring element widely distributed in the earth's crust. It is the 51st most abundant element on earth, with an average level of 1.8 mg arsenic/kg of the earth's crust. In the environment, arsenic occurs in rocks, soil, water, air, and in biota. Average concentrations in the earth's crust reportedly range from 1.5 to 5 mg/kg (Cullen, 1989). Higher concentrations are found in some igneous and sedimentary rocks, particularly in iron and manganese ores (Welsh, 1988). In addition, a variety of common minerals contain arsenic, of which the most important are arsenopyrite (FeAsS), realgar (AsS), and orpiment (As_2S_3). Natural concentrations of arsenic in soil typically range from 0.1 to 40 mg/kg, with an average concentration of 5 to 6 mg/kg (NAS, 1977). Normal background concentrations are 0.02-2.8 ng/m^3 in the atmosphere, and less than 1 ug/L in aquatic environment (Technische Universitat Bergakadenie Freiberg, 2001). However in many parts of the world, including Bangladesh and neighboring Nepal and West Bengal, groundwater is contaminated with very high levels of arsenic. Its presence poses a serious health concern to the population, which depends on groundwater for its drinking water and irrigation needs.

Chemically, there are two types or arsenic compounds: inorganic and organic. Inorganic arsenic in the environment is typically present in either trivalent or pentavalent form. Inorganic arsenic tends to be more toxic than organic arsenic. The trivalent arsenic (Arsenite, As III) is 60 times more toxic than the pentavalent arsenic (Arsenate, As V) (Fazal, 2000). Four types of dissolved arsenic compounds are typically most abundant in natural waters: Arsenite ($H_2AsO_3^-$) and Arsenate ($H_2AsO_4^-$), which are inorganic, and Methyl arsenic acid ($CH_3AsO(OH)_2$) and Dimethyl arsenic acid ($(CH_3)_2As(OH)$) which are organic (Fazal, 2000).

2.2 ORIGIN OF ARSENIC IN THE ENVIRONMENT

Arsenic is released to the environment from a variety of natural and anthropogenic sources. Through erosion, dissolution, and weathering, arsenic can be released to ground water or surface water. Geothermal waters can be sources of arsenic in ground water, particularly in the Western United States (Nimick, 1998). Dominant natural processes are volcanic activities and weathering of arsenic bearing rocks including realgar (AsS), orpiment (As_2S_3), arsenopyrite (FeAsS), and lollingite ($FeAs_2$) (USGS, 2001).

The origin of the groundwater contamination in Bangladesh has been extensively studied throughout the years. Two hypotheses are prevailing to describe the cause of the contamination in Bangladesh. These are: Pyrite Oxidation and Oxy-hydroxide reduction (Bridge, 2000 and Fazal, 2000). However, both hypothesis may be operative in the Ganges delta region and may be conjointly responsible for arsenic contamination. Since arsenic has only been discovered in Nepal in the past few years, its origin has not been studied. Nevertheless its geology is very similar to Bangladesh because of its geographical closeness to it. As such, the origin of the arsenic contamination in Nepal is probably similar to the one of Bangladesh. The following is an overview of some anthropogenic sources and of the two arsenic contamination prevailing theories of Bangladesh.

2.2.1 ANTHROPOGENIC SOURCES

Anthropogenic sources of arsenic relate to its use in the lumber, agriculture, livestock and general industries. Arsenic (III) oxide is used in the manufacturing of agricultural chemicals (pesticides), glasswares, industrial chemicals, copper, lead alloys and pharmaceuticals. In agriculture, arsenic compounds such as lead arsenate, copperacetoarsenite, sodium arsenicte, calcium arsenate and organic arsenic compounds are used as pesticides. Substantial amounts of methyl arsenic acid and dimethyl arsinic acid are used as selective herbicides. Chromated copper arsenite, sodium arsenate and zinc arsenate are used as wood preservatives. Some phenylarsenic compounds such as arsanilic acid are used as feed additives for poultry and swine. Arsenic is also extracted from the earth's crust through activities such as non-ferrous mining operations. Arsenic is also released from industrial processes, including the burning of fuels and wastes, mining and smelting, pulp and paper production, glass manufacturing, and cement manufacturing (EPA, 2003). In addition, past waste disposal sites may be contaminated with arsenic. As anthropogenic processes that release arsenic as a by-product are rare in South Asia, it is widely believed that the origin of the arsenic contamination is not man-made.

2.2.2 PYRITE OXIDATION HYPOTHESIS

Arsenic is assumed to be present in certain minerals (pyrites) that are deposited within the aquifer sediments. Due to the lowering of the water table below these deposits, atmospheric oxygen invaded the aquifers by diffusing into the pore spaces and into the groundwater. The oxygen interacted with the arsenopyirite, turned it into water-soluble form, thus releasing the arsenic into the groundwater (Bridge, 2000). The intensive irrigation development in the country supports the above hypothesis. Prior to 1995, most of the irrigation water in the country came from surface water sources. In 1995, the population started switching to groundwater as a source for irrigation water. The contribution of groundwater to the total irrigated area increased from 41% in 1982/1983 to 71% in 1996/1997, while the contribution of surface water steadily declined from 59% to 29% over the same period (NMIDP, 1998). According to this theory the extensive pumping of the groundwater probably caused the lowering of the water table, thus releasing the arsenic into the groundwater. Prior to this extensive pumping, a significant portion of the rural population was using groundwater as their main drinking water source. Yet, no cases of arsenic poisoning were reported in the country prior to the start of heavy irrigation pumping. Till only 1998, the groundwater in the Rangpur, Jamalpur and Bogra districts had been considered safe. It has been established now that the groundwater in these districts is heavily contaminated and numerous arsenic patients have been reported to live there. According to this theory the presence of arsenic in the environment is not in itself man-made, but its mobilization into the groundwater has been caused by anthropogenic activities.

2.2.3 OXY-HYDROXIDE REDUCTION HYPOTHESIS

Thousands of years ago, rocks rich in arsenic were eroded from the Himalayas and other high-lying source areas, and deposited along with sands, gravels, silts and clays in low-lying areas that now make up West Bengal and Bangladesh. These arsenic-bearing sediments became buried over thousands of years, forming part of the aquifers that are being tapped today. A study has found that the arsenic sediment has been released into the ground water by a natural process called “oxyhydroxide reduction”. In this process, arsenic is released into the surrounding water when fine-grained iron or manganese oxyhydroxides dissolve due to natural conditions that lead to a decrease in oxygen levels (British Geological Survey, 1999).

2.3 ARSENIC CONTAMINATION IN SOUTH ASIA

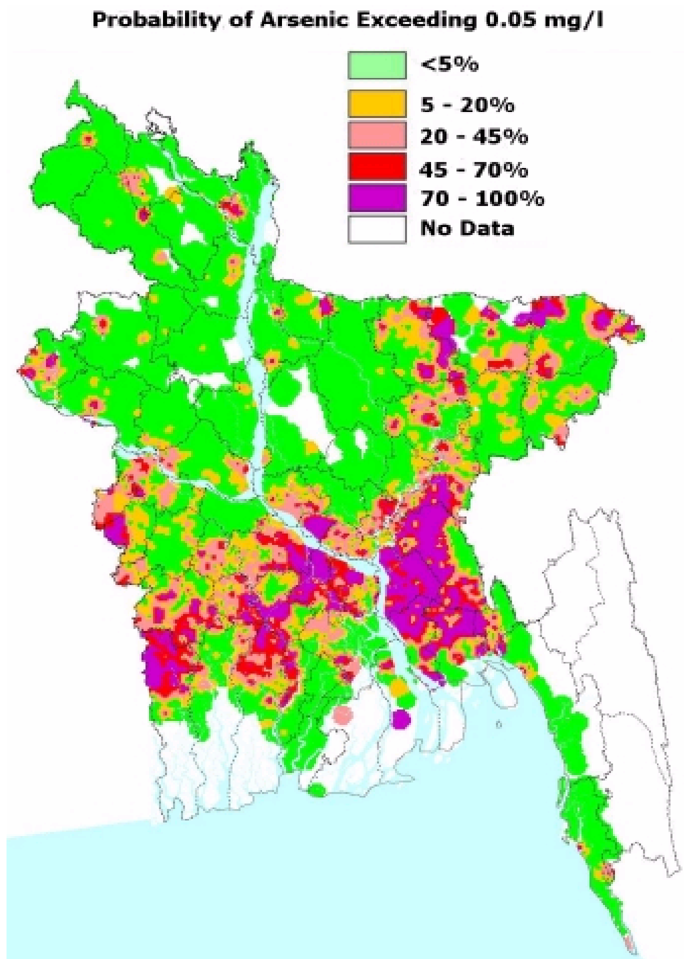
Due to its disastrous health effects, the World Health Organization (WHO) has set the maximum contaminant level (MCL) for arsenic in drinking water to 10 μg/L. The governments of Bangladesh, India and Nepal, countries that have their own arsenic contamination problems have set an “interim-arsenic standard” 50 μg/L, thereby setting a target to be achieved in arsenic contaminated regions.

Traditionally, most of South Asia’s rural population got its drinking water from surface water sources, but these sources often had a high microbial contamination content. According to the World Bank more than a quarter of a million children died every year from water-borne diseases in West Bengal (Crisis Information Center, 2003). As such the United Nations started encouraging the rural populations of many countries throughout the world to use groundwater as their main water source. The water is usually pumped from underground tubewells, which are relatively cheap to install and operate. Tubewells are PVC cylinders sunk into the ground to varying depths to provide underground water for irrigation and drinking. Bangladesh and West Bengal started the switch in the mid 1970’s while Nepal started it in the early 1980’s (Environmental and Public Health Organization, 2001). Unfortunately, the presence of arsenic in groundwater is not readily apparent to users as it does not alter the physical water quality (taste, smell, color, etc.), and the symptoms of arsenic poisoning are undetectable in its early stages. Therefore the groundwater was never tested initially for its arsenic content, only for its microbial contamination. The arsenic testing began later on, when most of the tubewells were installed and already in operation and some villagers started showing symptoms of arsenic poisoning. The results were disturbing: very high concentrations were found in a big portion of the samples. The following section will try to address the extent of the arsenic contamination problem in each of these three places: Bangladesh, West Bengal and Nepal.

2.3.1 BANGLADESH

According to the Bangladeshi Ministry of Health and Family Welfare, by the mid-1990's almost 97% of the population had access to safe water through more than 4 million tubewells. A UNICEF-funded Department of Public Health Engineering (DPHE) testing program, which began in 1996 and has tested so far some 51,000 tubewells, has found arsenic contamination in the central part of the country, stretching from Chapai Nawabganj in the west to Brahmanbaria in the east. The greater Sylhet area is also affected. Isolated cases of arsenic contamination have been found in the northern and coastal areas of the country (see Figure 3). The DPHE-UNICEF testing program is the largest one to date. As of today, the program has analyzed samples from tubewells in 61 out of 64 districts across the country. It has found arsenic contamination above the permissible level of 50 μg/L in 211 of the country's 460 districts known as *thanas*. Arsenic contamination has been found in 29 % of all wells tested. In other words, 7 out of 10 wells tested have been found to be safe from arsenic contamination. Due to arsenic contamination, safe water access is estimated to have dropped from 97% to 80% nationwide (Adeel, 2001).

Figure 3: Extent of arsenic contamination in Bangladesh (Crisis Information Center)



Of West Bengal, Nepal and Bangladesh, the latter is the one that has the biggest arsenic problem. The Bangladeshi Ministry of Health and Family Welfare indicates that more than 10000 arsenicosis patients (arsenic poisoning patients) have been reported so far (Adeel, 2001). According to a British Geological Survey study in 1999 on shallow tube-wells in 61 of the 64 districts in Bangladesh, 46% of the samples were above 10 μg/L and 27% were above 50 μg/L (British Geological Survey, 1999). When combined with the estimated 1999 population, it was estimated that the number of people exposed to arsenic concentrations above 50 μg/L is 28-35 million and the number of those exposed to more than 10 μg/L is 46-57 million (Mahmood, 2002). This problem has the potential of evolving into a huge social disaster as millions of people in rural areas are slowly but surely being poisoned. The effects of arsenic contamination on the economy and society will be examined in detail later on in this paper.

2.3.2 WEST BENGAL

Arsenic contamination in West Bengal, India was first reported in December 1983 when 63 arsenic patients from 3 villages were identified. At present 3000 villages are arsenic affected. It has been established that 9 districts in West Bengal have arsenic concentrations in their groundwater that are higher than 10 μg/L. The area and population of these 9 arsenic affected districts are 38865 km^2 and 42.7 million respectively. When combined with the estimated population, it was estimated that the number of people exposed to arsenic concentrations above 50 μg/l is 1 million and the number of those exposed to more than 10 μg/L is 1.3 million (WHO, 2001). As part of an arsenic study, the School of Environmental Studies of Jadavpur University clinically examined 95,000 people from arsenic affected districts of West Bengal. It indicated that 10100 people (9.4% including 2% children) were registered with arsenical skin lesions. The study also consisted of testing water samples collected from 10,000 tube wells. Out of them, 51% were classified as being unsafe to drink according to the WHO guideline (Uttam, 2000).

Figure 4: Extent of arsenic contamination in West Bengal (Crisis Information Center)

2.3.3 NEPAL

Due to its proximity to Bangladesh and West Bengal, various groups became concerned in the late 1990's that a similar arsenic contamination problem could be present in Nepal. In 1999, the Department of Water Supply and Sewerage (DWSS) received financial support from the WHO and UNICEF to initiate various arsenic monitoring programs. In one of its 1999-2000 studies conducted in the districts of Jhapa, Morang and Sunsari, DWSS found that 9% of the 268 tube well water samples contained arsenic above the WHO standard (Nepal Red Cross Society, 2000). An MIT study conducted by Patricia Halsey found that 18% of the tube wells tested in the Terai region of Nepal contained arsenic over 10 μg/L (Murcott, 2002). The Nepal Red Cross Society reported that 30 out of 590 (5.1%) of the tube well water samples from the districts of Jhapa, Saptari and

Sarlahi in the Eastern Terai contain over 10 μg/L of arsenic. In the district of Nawalparasi in Central Terai, ENPHO tested 164 tube wells and found arsenic concentrations of over 10 μg/L in 57 of the wells (35%) (Nepal Red Cross Sociey, 2000). Another MIT study performed by Tommy Ngai found arsenic concentrations as high as 863 μg/L in the area around Butwal (Ngai, 2002). It can be inferred from these studies that arsenic contamination of the groundwater seems to be limited to the Terai region of Nepal. Furthermore, the tube wells that are currently in use in Nepal have only been dug in the early 1980's (Environment and Public Health Organization, 2001). As such the ugly symptoms of arsenicosis are only beginning to emerge, leaving more doubt on the extent of the contamination. A description of the various arsenic studies in Nepal is shown in section 4.2 of this report.

3.0 IMPACTS OF ARSENIC CONTAMINATION

The impacts of arsenic contamination are three-fold: health, social and economic. These three are interdependent as the health impact of arsenic contamination triggers the social impact, which in turn triggers the economical one.

3.1 HEALTH IMPACT

Arsenic compounds are toxic to humans and depend mainly on their chemical form, route of entry, age, sex, doses and duration of exposure.
The symptoms of arsenicosis, or arsenic poisoning usually appear in the following stages:

i) Initial stage: Desmatities, keratities, conjunctivities, bronchities and gastroenterities.
ii) Second stage: Peripheral neuropathy, hepatopathy, melanosis, depigmentation and hyperkeratosis.
iii) Final stage: Gangrene in the limbs, malignant neoplasm, and cancer. (WHO, 2000)

The health effects of arsenic can be divided into non-cancer health effects and cancer health effects.

3.1.1 NON-CANCER HEALTH EFFECTS

The most widely noted non-cancer effects of chronic arsenic consumption are skin lesions. The first symptoms to appear after initiation of exposure are hyperpigmentation (dark spots on the skin) and hypopigmentation (white spots on the skin). Some physicians collectively refer to these symptoms as melanosis. Over time arsenic exposure is associated with keratoses on the hands and feet. Keratosis is a condition where the skin hardens and develops into raised wart-like nodules. These nodules become more pronounced over time, sometimes reaching 1cm in size (WHO, 2000). Five years usually elapse between first exposure and initial cutaneous manifestations. However this period can differ widely from patient to patient, depending on the quantity/volume of arsenic ingested, nutritional status of the person, immunity level of the individual and the total period of arsenic ingestion.

3.1.2 CANCER HEALTH EFFECTS

The International Agency for Research on Cancer classified inorganic arsenic compounds as skin and lung (via inhalation) carcinogens (WHO, 2000). The WHO estimates that its guideline value of 10 µg/L is associated with an excess lifetime risk for skin cancer of $6x 10^{-4}$ (or six persons in 10,000). High levels of arsenic in drinking water are also reported to be associated with a number of internal cancers such as bladder, liver and stomach cancers (WHO, 2000). However the studies completed so far have not yet established a definite connection between arsenic ingestion and these latter forms of cancer.

3.2 SOCIAL IMPACT

3.2.1 SOCIAL OSTRACISM

The social impact of arsenic poisoning flows directly from its impact on the health of the population. The impact can be summarized by the social ostracism of the affected people. The social ostracism of arsenic patients can be of the following forms:

- The affected are refused water from the neighbors tube-wells;
- The affected are being avoided or discouraged to appear in public;
- The affected children are being debarred from attending schools, the adults discouraged to attend offices, go shopping, visit medical professionals in the hospital etc.
- Affected young women are being compelled to stay unmarried;
- Diseased married women are being sent back to their parents with children;
- Arsenicosis of one jeopardizing the lives of both members of a couple;
- Eligible persons are refused jobs when found to be suffering from arsenicosis;

- Mistaking the skin disorder for leprosy or some other contagious disease and resultant quarantine;

Yet another societal impact is that on livelihoods of families that lose the head of the household or "bread-winners" to the disease. There is a need for serious consideration of alternative livelihoods for people who may be affected by arsenicosis as well as for the orphans and widows of those who pass away.

3.2.2 ARSENICOSIS AND HOUSEHOLD INCOME: THE POOR SUFFER MOST

A Study by the World Health Organization established a correlation between income and the probability of contracting arsenicosis. This correlation was established mathematically in the form of the following logit regression:

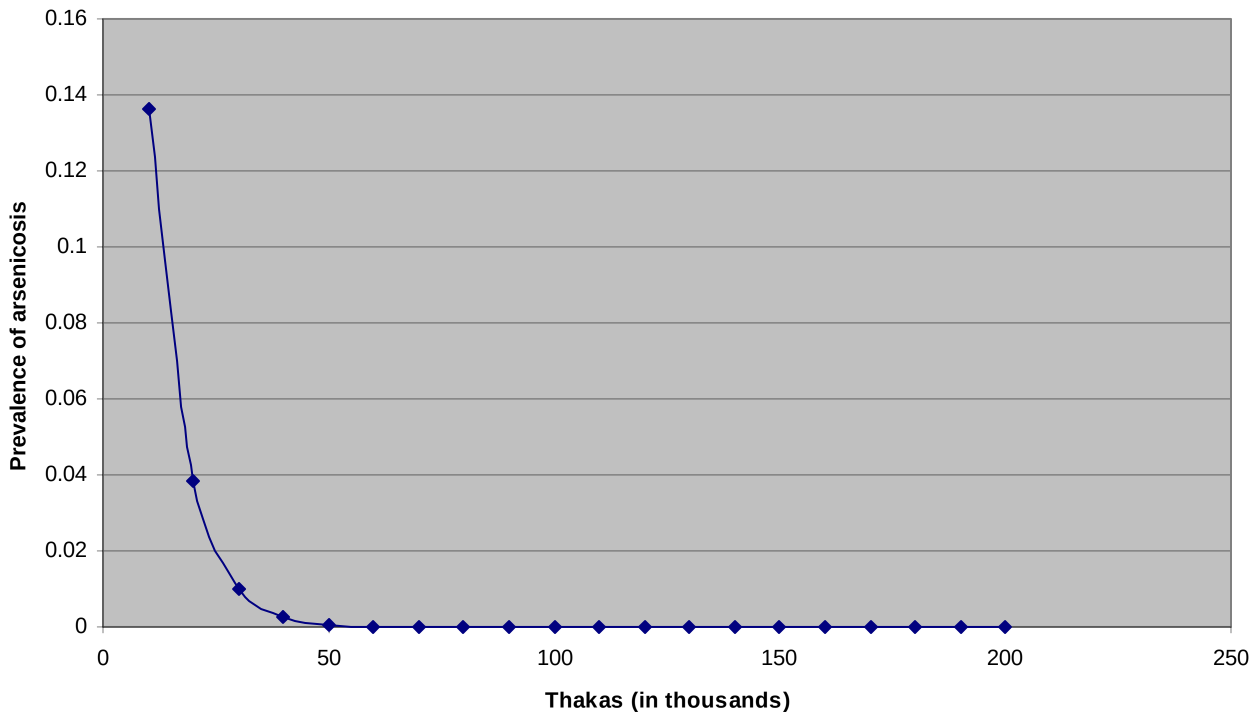
$$\text{Ln } Pi/(1-Pi) = -0.0968 - 0.07168YI$$
$$R^2 = 0.385$$

Ln Pi /(1-Pi) is the log of the odds ratio of arsenicosis. The odds ratio is the ratio of the probability that the person will have arsenicosis to the probability that the person will not have arsenicosis (WHO, 2000). YI represents the household income.

By plotting Pi as a function of Yi (see Figure 5) we can infer that there is a negative relationship between the prevalence of arsenicosis and household income. Increasing levels of household income are associated with a lower prevalence of arsenicosis. The burden of arsenicosis falls therefore mainly on low-income families. Although it cannot be inferred from the above formula, the WHO has established, through surveys, that households earning more than 140,000 Thakas per year (56 Thakas=1USD) had no arsenic patients. The causes of the relationship between household and disease can be enumerated as follows:

- According to the National Research Council: "Variability in arsenic metabolism appears to be important in understanding the human response. There is evidence that methylating capacity differs among individuals and population groups. Different capacities would result in variations in tissue concentrations of arsenic". In humans, the liver methylates the most toxic form of arsenic, inorganic arsenic. It appears that people that consume a diet low in protein, and in particular the amino acid methionine, have a substantially low methylating capacity. These people are usually from low-income households, and as such are more susceptible to contract arsenicosis.
- It has been observed in Bangladesh, that high-income households can afford to buy reservoirs to store their water after it is pumped from the tube wells. As water is stored for long periods of time, the iron oxide settles at the bottom of the reservoir and this enhances the concentration of arsenic in the sludge. Thus, inadvertently, the storage of the water acts as a primary arsenic removal mechanism.
- It has also been observed in Bangladesh that access to tube well drinking water is at least partially determined by social status. High-income families sometimes have priority in accessing tube wells that are known to pump arsenic free water (WHO, 2000).

Figure 5:Relationship between prevalence of arsenicosis and household income



3.2.3 ARSENICOSIS AND GENDER: THE WOMEN SUFFER MOST

According to the WHO, women in South Asian countries are more susceptible than men to suffer from the arsenic contamination (WHO, 2000). As it was established in the previous section, bad nutrition has been linked to an increased vulnerability to arsenic poisoning. The nutritional levels of women in South Asia are frequently deficient for reasons linked with cultural norms and reproductive function. As such they are more at risk then their male counterparts. Furthermore, once members of a household contract arsenicosis, a significant amount of attention is paid to the “breadwinners”, or the men, sometimes to the detriment of the women. This can mean, for example, that most of the treatment costs will be spent on improving the health of the men. It is also common to reduce the household’s consumption of food to cope with the burden of the medical costs of arsenicosis. This can, in turn, reduce further the nutritional level of women, thus making them even more vulnerable. (WHO, 2000)

3.3 ECONOMIC IMPACT

The economic impact of arsenicosis flows directly from its social impact. This paper will try to examine the economic impact of this problem both on the household level and on the national level.

3.3.1 HOUSEHOLD LEVEL

Once family members become sick, various coping mechanisms come into play. As stated earlier a significant amount of attention is paid to the illness of the “breadwinners”. Nevertheless, regardless of the status of the affected person, the priority for the family becomes coping with the burden of the medical treatment costs. The coping strategy usually follows the following pattern:

1) Sale of assets: These assets can be factors of production such as land, or small assets such as beds, tables, chairs, radio. If the sold assets are factors of production, then the future income of the household could be significantly effected (Adeel, 2001). If a rural household is compelled to sell part or all of its land, it will loose its main source of income: selling of crops.
2) Reduction of food consumption or other consumption of basic needs: Families may be compelled to reduce whatever meager share they spent on education. This will annihilate the hope of the children of the household to break from poverty through education (WHO, 2000).
3) Getting loans: Some households may try, as a last resort, to get loans to finance lost income as a result of the breadwinner’s illness. This action is especially dangerous, as it will trap the family into a vicious circle. As the medical bills keep piling up, the family will be compelled to get more loans that they will not be able to repay because they lost their main source of income. Only when the

"breadwinner" recovers, which might never happen, will the family be able to repay the loans. Of course, by that time, these probably have gotten to very high levels due to the interest, leaving doubt as to the capacity of the household of ever repaying them (WHO, 2000).

3.3.2 NATIONAL ECONOMY LEVEL

A large scale poisoning of the population is bound to have a negative effect on the economy of the nation. Since the arsenic poisoning problem is not as widespread in West Bengal and in Nepal as it is in Bangladesh, its effects on the economy are probably limited. However, the arsenic problem in Bangladesh has a potential of affecting the economy on a large scale. The effects on the household levels described above can translate into effects on the economy as a whole. Some of these are described below:

- The arsenic problem can affect the already shattered educational status of these countries. This will, in turn affect in a negative way the economy of these countries. When a "breadwinner" gets sick, the children of the household often have to take his place. They can start working in the fields, or could be involved in selling goods or foods at the market place. Hence they will not be able to attend school anymore. Also, as stated above, the occurrence of arsenicosis in a household is often followed by a reduction in the amount allocated by the household to education.
- The arsenic problem leaves a huge burden on the government of these countries, especially Bangladesh, to try to remediate it. This remediation will come at a cost, as only part of it will be financed by NGO's or other international organizations such as the United Nations. Most of the funding will have to come from internal sources or from outside loans. This means that the government will have to cut some of its social and economic development programs to cope with this new disaster.
- The arsenic problem will also have a huge effect on the agriculture of the nation when contaminated groundwater is extensively used for irrigation purposes, as it

is in Bangladesh. Arsenic was found above permissible limits in vegetables, fruits and cereal crops grown in soils irrigated with contaminated water. Beyond the obvious health risks, it also creates a substantial long-term economic risk. Bangladesh's economy depends heavily on agricultural exports. As the international media is covering the arsenic contamination problem more and more, international consumers could become reluctant to purchase Bangladeshi products. Consequently, the amount of agricultural exports could decrease, contributing to the progressive decline of the economy.

4.0 STUDY DESIGN

4.1 OVERALL ARSENIC STUDY IN NEPAL

As stated in section 2.3.3 of this report, the first arsenic testing campaign was conducted in 1999-2000 by DWSS in cooperation with members of the MIT Nepal Water Project team of 2000. Since then, two organizations, Rural Water Supply and Sanitation Support Program (RWSSSP) and the Japan/Nepal Red Cross have been deeply involved in issues related to the arsenic problem in Nepal. As stated in section 2.3, the rural population of Nepal started switching their drinking water supply from surface water to groundwater in the early 1980's. RWSSSP and the Japan/Nepal Red Cross installed a big portion of the tubewells that are currently being used by the population to pump groundwater. As such, when arsenic was discovered in the water pumped from these wells, these two organizations felt responsible for ensuring that it is safe to drink. They each engaged in a campaign to test their wells for arsenic content and to distribute arsenic filters to the households using their wells. Each organization is conducting its campaign independently from the other, yet some information is being exchanged on an informal basis. Most of the shared information consists of arsenic papers written by third parties and arsenic filter test results (Three-Kolshi, Two-Kolshi and Arsenic-Biosand). An informal group meeting is conducted on the first week of every month to exchange this information. This group consists of: ENPHO, RWSSSP, Japan Red Cross, Nepal Red Cross as well as other organizations. (Environment and Public Health Organization, 2001)
A description of these organizations and the work they conduct is offered below.

<u>RURAL WATER SUPPLY AND SANITATION SUPPORT PROGRAM (RWSSSP)</u>
RWSSSP was established in 1989 as a joint program between the two governments of Finland and Nepal. It is based in Butwal and operates in the following districts: Nawalparasi, Kapilvastu, Rupendehi, Arghakahnchi, Gulmi and Palpa. Its main objective is to build new water supply systems and to improve sanitation in the covered districts. RWSSSP is largely funded by the Finnish Development Aid Agency, which is

administered through a Finnish consulting company, Plancenter Ltd. Placenter has been providing technical support to the Program since its creation through Finnish professional expatriates and local Nepali consultants.

RWSSSP has an arsenic section that consists of three people in charge of RWSSSP's arsenic program in the three districts under its jurisdiction. The arsenic program consists of the following:

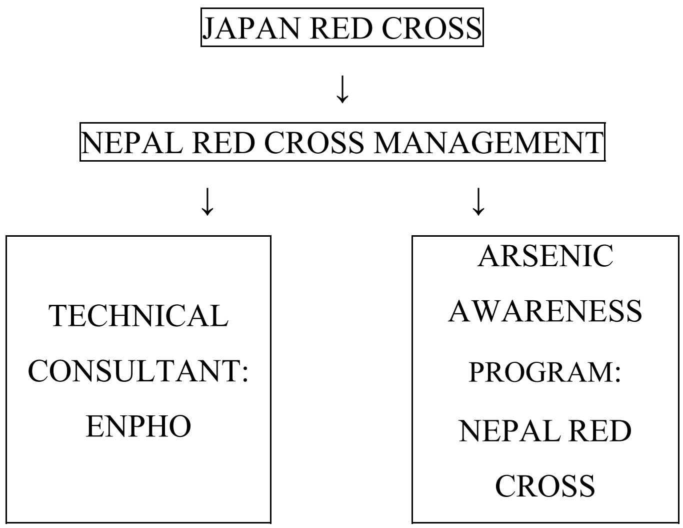
- Regularly monitor the RWSSSP wells for arsenic content;
- Distribute free of charge arsenic removal filters to all households using RWSSSP wells;
- Distribute free of charge the chemical tablets necessary to operate the Two-Kolshi filter to all the households using it;
- Regularly test all the distributed filters for arsenic removal rates;
- Promote arsenic awareness in all the households using filters distributed by RWSSSP. This is apparently being done on an informal basis in the sense that arsenic technicians engage villagers on arsenic related topics while doing their well and filter testing rounds;

JAPAN/NEPAL RED CROSS

The Nepal Red Cross has installed since the beginning of the 1980's more then 12,000 tubewells in the Terai (Environment and Public Health Organization, 2001). When it became apparent in January 2000 that some of these wells might be contaminated with arsenic, the Japan Red Cross and the Nepal Red Cross decided to take action. A three-year project called the Drinking Water Quality Improvement Program (Environment and Public Health Organization, 2001) was initiated to detect the arsenic contaminated tubewells of the Terai and to mitigate the problem. Under this Program the Nepal Red Cross personnel is in charge of all of the arsenic programs on the ground while the Japan Red Cross provides the funding and general guidelines. The DWQIP covers all the wells installed by the Nepal Red Cross in the Terai. The Nepal Red Cross has hired Environment and Public Health Organization (ENPHO), a non-profit laboratory based in

Kathmandu to be in charge of the technical component of the Program. An organizational chart of the various actors involved in the DWQIP is shown in Figure 6 as well as a description of their respective tasks.

Figure 6: Organizational Chart of Drinking Water Quality Improvement Program



As shown in the above chart, the Nepal Red Cross is in charge of promoting arsenic awareness in the villages under its jurisdiction through arsenic awareness meetings. These meetings usually consist of a talk given by arsenic technicians followed by a question and answer period. The talk component is often accompanied by visual aids such as posters, pictures or when electricity is available, a video.

The tasks of ENPHO under DWQIP are as follows:

- Arsenic Surveillance: It consists of regularly monitoring the Nepal Red Cross wells for arsenic content (see Table 1 for a list of ENPHO's results);
- Treatment Options: It consists of determining the best options and then evaluating a range of arsenic treatment alternatives that might be feasible in Nepal;
- Filter Distribution: It consists of distributing free of charge arsenic removal filters to all households using ENPHO wells. According to Upendra Baudel, the ENPHO

arsenic technician in charge of the DWQIP in Nawalparasi, more then 100 Two-Kolshis, about 50 Three-Koshis and 6 Arsenic-Biosand filters have been distributed as of January 2003 in the following districts: Nawalparasi, Parsa, Bara, Bardiya and Rautahat. According to same technician, the DWQIP is planning on distributing 500 additional filters in the summer of 2003. The type of these filters has not been decided yet by the Program;

- Filter Testing: It consists of continuously test all the distributed filters for arsenic removal rates;
- Tablet distribution: It consists of regularly distributing free of charge the chemical tablets necessary to operate the Two-Kolshi filter to all the households using it

In addition to all the tasks listed above, ENPHO is conducting a pilot study of the Arsenic-Biosand filter to determine whether it can be distributed on a wide-scale to all the affected households. Although this task was not originally part of the scope of the DWQIP, it became part of it under the recommendation of arsenic technicians working for ENPHO.

Table 1: Result of ENPHO's testing as of August 2001

District	0-10 μg/L	11-50 μg/L	Above 50 μg/L	Total	% >50 μg/L
Jhapa	296	36	0	332	0
Sarlahi	257	41	1	299	0
Saptari	264	36	0	300	0
Bara	783	69	12	864	1
Parsa	1593	201	49	1843	3
Rautahat	393	556	110	1059	10
Nawalparasi	323	283	105	711	15
Kapilvastu	568	42	2	612	0
Rupandehi	518	117	2	637	0
Banke	461	62	8	531	2
Bardiya	3000	109	19	428	4
Moreng	11	0	0	11	0
Sunsari	6	0	0	6	0
Udayapur	3	0	0	3	0
Dhanusa	10	0	1	11	9
Mahottari	2	0	0	2	0
Chitwan	15	0	0	15	0
Total	5803	1552	309	7664	4

All the personnel participating in the DWQIP undergo an extensive training program. Some senior personnel have even been sent on educational tours to other areas in South Asia that suffer from a similar arsenic contamination problem. An expose of these tours is offered below:

- Visit to Bangladesh: 3 persons from ENPHO and 1 person from the Nepal Red Cross visited Bangladesh in September 2000. The team visited several organizations (Water Aid, UNICEF, WASA, NIPSOM…) involved in arsenic mitigation activities. The team also visited several arsenic affected villages where they saw arsenicosis patients and various household treatment options.

- Visit to Calcutta: In February 2001, a team of 3 members of the DWQIP attended a 3-day Symposium on Waste Management and Bengal Basin issues. They also took this opportunity to visit several organizations involved in arsenic issues in West Bengal such as: UNICEF, Ramakrishna Mission, Jadhavpur University and Chemito (a laboratory instrument supplier).
- Training for detection of arsenic in biological samples (hair and nail) at Jadavpur University: Analytical chemists working for the DWQIP were sent to Jadavpur University in Calcutta to gain some knowledge on water and biological samples (hair and nail) analysis and on the various equipments required in this process. This training was conducted by Prof. Dipankar Chakaroborti, the Director of the School of Environmental Sciences at the university and a leading figure of the Arsenic issue in India. (Environment and Public Health Organization, 2001)

4.2 CURRENT ARSENIC STUDY

4.2.1 STUDY OBJECTIVES

As explained in the previous section, three types of arsenic removal technologies have been distributed so far: Arsenic-Biosand, Three-Kolshi and Two-Kolshi. These filters are currently been tested extensively on a technical level by various organizations. However, no comprehensive social acceptability study has been done so far of these three filters. I traveled to Nepal in January 2003 as part of the Nepal Water Project team to do the first one of these studies. My study tried to answer the following two questions related to the social acceptability of the three currently available types of arsenic removal filters:

- What is the level of arsenic awareness of the affected population?
- What is the social acceptability of each of the three types of filters?

In order to answer these questions I decided to conduct a survey at the household level in some affected districts of Nepal. The survey instrument was drafted in Cambridge in the fall of 2002 using a methodology described in Chapter 7. The results of this survey are described in Chapter 8 and the conclusions drawn from them in Chapter 9.

With the interest of making my study as complete as possible, I also decided to conduct a technical evaluation of the filters, namely measuring their arsenic removal rates. In addition I would try to assemble as much as possible previous results of the various NGO's on the ground. All these results are given in Chapter 6 of this report.

RWSSSP provided all the logistics and personnel required to conduct the study. They provided me with a four by four Toyota and a driver on a daily basis so that I could visit the arsenic contaminated villages. In addition they provided me with a translator that helped me conduct the survey component of my study. During my whole stay in Butwal, I stayed, free of charge, at their guesthouse. A schedule of my site visits is included in Appendix III of this report.

4.2.2 FIELD SITE

This study was conducted in three districts in the Terai region of Nepal: Nawalparasi, Rupandehi and Kapilvastu. A map of these three districts is shown in Figure 7.

Figure 7: Map of Visited Districts

The Terai region is composed of a 26 to 32 km wide broad belt of alluvial and fertile plain in the southern part of the country. This belt extends from the westernmost part of the country to the eastern limit and covers about 17% of the total land area.

Figure 8: Picture of Terai

The major ethnic groups of the Terai are as follows: Brahman and Rajputs, Tharus, Rajbansis, Satars and Masalmans (Nepal's People and Ethnic Groups, 2003). The surveyed villagers in this study were either Brahman/Rajputs or Tharus.

Brahman and Rajputs

These are the two largest groups distributed in scattered patterns all over the country and are considered as the two highest castes in Nepal. They have sharp Indo-Aryan features and an olive complexion. Brahmins are believed to have migrated from India while Chhetris are from the present day Khasa people from Khasi (Nepal's People and Ethnic Groups, 2003). Hinduism is the main religion of these groups. They speak Nepali, the national language of Nepal, and use a script which is derived from Sanskrit.

Tharus

This is the largest and oldest ethnic group of the Terai belt. These people are found living in close proximity to densely forested regions. They have traditionally been isolated from the neighboring cultures and peoples as they lived in villages located in the malaria-infested jungles of the Gangetic plains. As such they developed a unique culture free from the influence of adjacent India, or from the mountain groups of Nepal (Meyer, 2003). They are dark in complexion and have smart, trim bodies. They follow the Hindu religion and their practices are dependent on many typical Aryan practices (Nepal's People and Ethnic Groups, 2003). They have their own language, also called Tharu, which is quite different from Nepali.

5.0 ARSENIC REMOVAL TECHNOLOGIES

5.1 THREE-KOLSHI

A "kolshi" is the clay water pitcher used for collecting water throughout Bangladesh, Nepal and much of South Asia. The Three-Kolshi filter consists of three kolshis stacked on top of the other (see Figure 9). The top two kolshis are perforated at the bottom to allow water to pass through them. Each kolshi contains different materials with a specific function:

- The top kolshi contains 3 Kg of iron fillings (representing about 1/6 of the total kolshi volume) and 2 Kg of coarse sand. About one third of the kolshi contains materials while the rest of the volume is occupied by raw water.
- The middle kolshi contains 2 kg of fine sand and 1kg of wood charcoal of a consistent size, avoiding fine wood ash, which dissolves and produces an undesirable basic water solution. Materials occupy about one sixth of the kolshi.
- The bottom kolshi is simply a collection container. Filtered water collects in this recipient and is directly decanted from it for use.

Figure 9: Three-Kolshi filter

The filter is very easy to operate. The raw water is poured into the top kolshi and allowed to percolate through the top two kolshis into the bottom one.

The arsenic removal process associated with this filter is fairly simple. The raw water causes the iron filings to rust thus creating ferric oxide. The arsenic will sorb onto the ferric oxide particles and then percolate down the system with the water. The sand contained in the top two kolshis will trap these particles, along with the arsenic sorbed onto them. The arsenic content of the water collected in the bottom kolshi should then be a tiny fraction of the arsenic content of the original raw water. (Murcott, 2000)

5.2 ARSENIC-BIOSAND FILTER

An M.Eng alumnus, Tommy Ngai designed this filter. Mr. Ngai was part of the January 2002 MIT Nepal Water Project where his thesis was to test arsenic speciation in various wells in the Terai. He then won a research prize, the Lemelson International Award, at the MIT IDEAS competition, for his design of the Arsenic-Biosand filter. The prize allowed him to conduct two other field visits to Nepal in September 2002 and in January 2003.

His design combines two existing technologies: the Three-Kolshi system used for arsenic removal and the Biosand filter used for bacterial removal.

The combined-filter design consists of a concrete biosand filter as shown in Figure 11. Refer to Figure 10 for a schematic diagram showing the major parts of the combined-filter. The construction of the combined-filter is simple. First, a concrete mold is built, with a plastic pipe connected to the bottom. Gravel, coarse sand and fine sand are placed in the concrete mold. Then, a square metal diffuser is constructed. About 5 Kg of iron nails are then added on top of the diffuser. Finally, the filter is capped with a metallic cover to avoid the introduction of any outside contamination into the filter. In about two weeks, a biofilm layer will be fully grown on top of the fine sand layer. This biofilm will kill any pathogens that are present in the raw water that is poured in the filter.

The filter is very easy to operate. The raw water is poured into the filter from the top and allowed to percolate through it. The treated water will then come out from the plastic pipe at the bottom. It can be collected by any recipient placed under the pipe.

The arsenic removal process associated with this filter is similar to the Three-Kolshi one. The raw water causes the iron nails to rust thus creating ferric oxide. The arsenic will sorb onto the ferric oxide particles and then percolate down the system with the water. The sand contained in the filter will trap these particles, along with the arsenic sorbed onto them. The arsenic content of the water collected from the plastic pipe should then be a tiny fraction of the arsenic content of the original raw water.

Figure 10: Schematic diagram of the Arsenic-Biosand filter (Ngai and Walejwick, 2003)

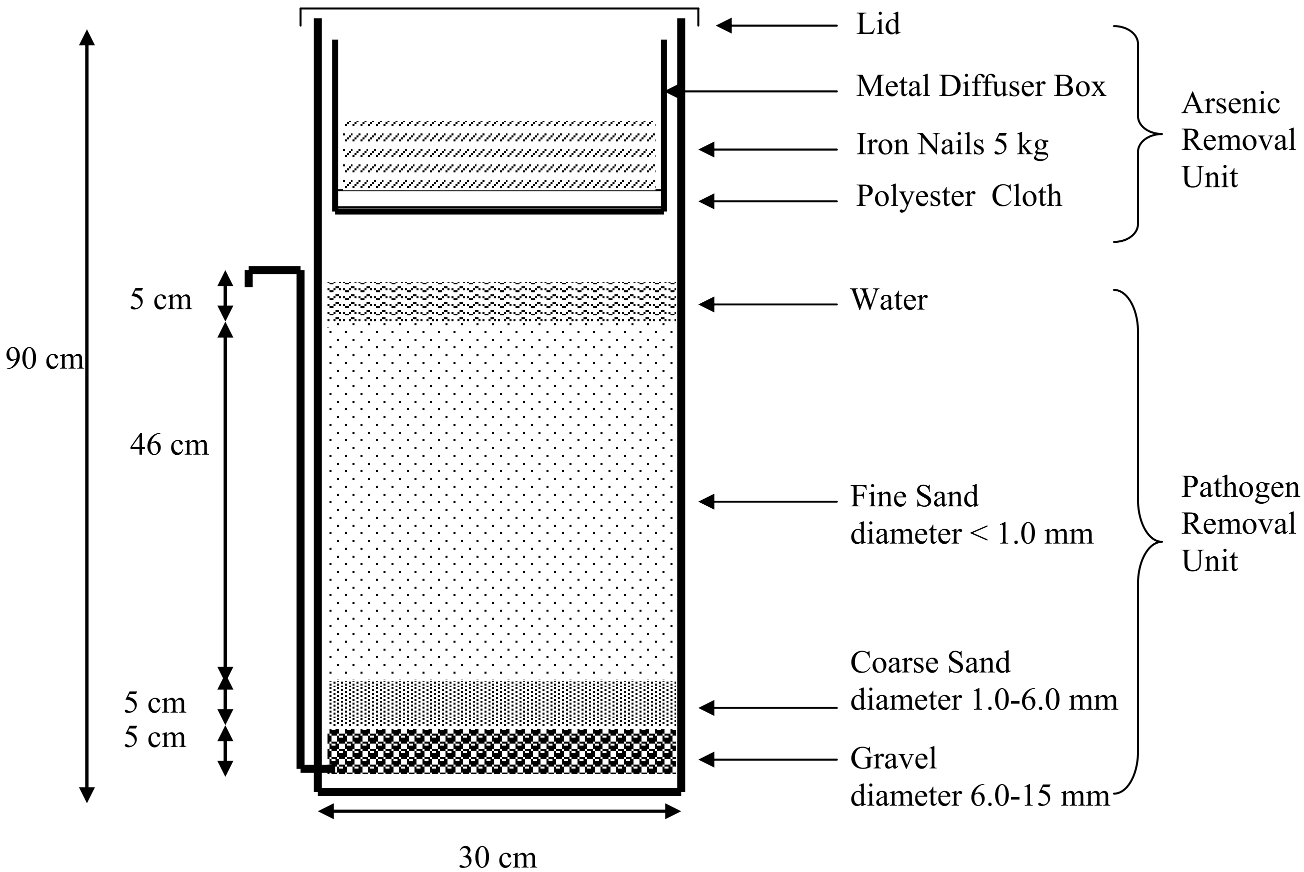


Figure 11: Arsenic-Biosand filter in the backyard of a house in Sarawal

5.3 TWO-KOLSHI

The system consists of a 20-liter plastic mixing bucket, a filtration unit consisting of two Kolshis placed one on top of the other. In order to operate, the filter requires a regular source of a chemical packet manufactured and distributed by ENPHO. In this process arsenic is removed by coagulation and co-precipitation followed by filtration.

ENPHO's procedure for training households in the use of this system is as follows:

1. Collect approximately 20 liters of water in a bucket.
2. Pour the contents of 1 packet of chemicals into the collected water.
3. Stir vigorously using a wooden stirring rod for approximately 1 minute to achieve thorough mixing.
4. Allow settling for 30 minutes and then stir again in a similar manner for 1 minute. Repeat the same procedure every 30 minutes until 2 hours have passed since the initial mixing. However, do not stir at the 2 hours mark.

5. Pour the supernatant water into the filtration unit and dispose of the sludge into cow dung.
6. Collect the treated water from the spigot of the collection unit and use this water for drinking and cooking.

Each chemical packet weighs 4 grams and is used to treat 20 liters of contaminated water. The packet contains a 1:1 ratio, by weight, of ferric chloride and charcoal powder and 800 milliliters of 8% sodium hypochlorite solution. In this process the ferric chloride coagulates and adsorbs arsenic in co-precipitation:

$FeCl_3 + 3H_2O \rightarrow Fe(OH)_3\ (s) + 3Cl^- + 3H^+$

$Fe(OH)_3 + H_2AsO^-_4 \rightarrow$ Fe-As Complex

The precipitate is then filtered by the Two-Kolshi unit. Hypochlorite is used as an oxidant to facilitate the oxidation of arsenite to arsenate as arsenate is more effectively removed than arsenite. In addition, hypochlorite significantly reduces the microbial contamination of treated water. The charcoal powder is used as an adsorbent. It removes residual chlorine resulting from the use of hypochlorite and helps reduce other contaminants in the water. (Hwang, 2002)

Figure 12: Two-Kolshi filter in Sunwal

6.0 TECHNICAL EVALUATION OF FILTERS

6.1 ARSENIC METHODS

The Arsenic Check Field Test Kit by Industrial Test Systems Inc. (ITS) was used to evaluate the arsenic content of water. In order to evaluate the arsenic removal rate of a filter, the influent water and the effluent water were analyzed for arsenic content. The removal rate of a filter can simply be subtracting the ration of the effluent concentration by the influent concentration from 1.

The test kit is relatively simple to operate and provides an immediate and fairly accurate result. The detection range is from <5 μg/L to 800 μg/L . The upper detection limit can be extended to 4000 μg/L by simply diluting the sample by one to five. The test kits include three chemical reagents, measuring spoons, a color chart, test strips and reaction bottles. The arsenic content of the sample is determined by colorimetry with each color corresponding to an arsenic concentration. The color chart starts at pure white for 0 μg/L of arsenic to a tint of yellow for 5 μg/L , to slightly more yellow for 10 μg/L . At a concentration of 500 μg/L the color is dark brown.

The test is conducted as follows:

1) Three pink spoons of reagent 1, tartaric acid, are added to the bottle. The bottle is capped and shaken for fifteen seconds. The content is then allowed to sit for two minutes.
2) Three red spoons of reagent 2, which contains a mixture of ferrous salts, are added to the bottle. The bottle is capped and shaken for fifteen seconds. The content is then allowed to sit for two minutes.
3) Three white spoons of reagent 3, zinc dust, are added to the bottle. The bottle cap is replaced with another cap with a special spout that allows a test strip containing mercuric bromide coating to be inserted into the bottle. The content is then allowed to sit for thirty minutes.

4) The test strip is taken out of the bottle and compared to the color chart to determine the arsenic concentration.

The whole process is based on the conversion of inorganic arsenic compounds in the tested water to arsine gas (AsH_3) by the reaction of zinc dust and tartaric acid. The arsine gas then reacts with the mercuric bromide on the test strip to form mixed mercury halogens that appear with a color change on the test strip.

The EPA published a study of the ITS test kit entitled "Environmental Technology Verification Report, Quick Arsenic Test Kit", in which it assesses its accuracy. The accuracy of the Test kit was evaluated by testing some samples for arsenic with both the test kit and the inductively coupled plasma mass spectrometry method (ICPMS). The EPA found that up to 96 % of the results obtained with the ITS test kit agreed within 25 % of the results obtained with the ICPMS method (EPA, 2002).

Tommy Ngai performed a similar accuracy study of the ITS test kit in his M.Eng thesis. He compared the results obtained with the ITS test kit with the results obtained with an EPA method called Graphite Furnace Atomic Adsorption Spectrometry (GFAAAS). He found that 78 % of the results obtained with the ITS test kit agreed within 25 % of the results obtained with the GFAAAS (Ngai, 2002).

Both the EPA and Ngai evaluated the accuracy of the test kit by the percentage closeness of its results with the results of a recognized laboratory method (ICPMS or GFAAAS). Both the EPA and Ngai found that the test kit yielded close results (within ± 25 %) to the laboratory method in most cases (respectively 96 % and 78 % of the cases). It can be inferred that the ITS test kit is an acceptable field method to measure arsenic in drinking water.

6.2 PERFORMANCE OF THE THREE ARSENIC FILTERS

This section will consist of showing the arsenic performance of the three filters as measured by four different sources: the author, Tommy Ngai, RWSSSP and ENPHO. The first three sources measured arsenic concentrations by using the ITS field test kit, whereas ENPHO used a laboratory method called hybride generation atomic spectrometry (HGAAS). HGAAS is an approved EPA analytical method for arsenic and have a good detection limit (MDL) of 1 μg/L (Hwang, 2002).

The author conducted his tests in the month of January 2003 when he visited Nepal with the MIT Nepal Water Project team. Tommy Ngai and his IDEAS competition teammate from Stanford University, Sophie Walewijk, undertook their tests in Nepal in December 2002 while they were conducting a study on the ABF as part of the RWSSSP. Their results come from a report they jointly wrote for RWSSSP: "The ABF Project" (Ngai, T and Walewijk, S, 2003). RWSSSP conducted its tests in the fall of 2002 and the results were given to the author by Kalawati Pokharel, the senior arsenic technician at RWSSSP. The ENPHO test results were taken from Jeff Hwang's thesis, a previous M.Eng student who conducted a study on the Two-Kolshi filter, and were conducted in the fall of 2001. The notation ND in the tables refers to concentrations less then 5 μg/L.

6.2.1 ARSENIC-BIOSAND FILTER

<u>Tommy Ngai</u>

Table 2: Results of Arsenic-Biosand from Tommy Ngai and Sophie Walewijk

Contact person	**Total Arsenic Concentration by ITS Test Kit**		**% removal**
	Raw ($\mu g/L$)	*Filtered ($\mu g/L$)*	
Min Chaudhary	160	15	91
Phagu N. Chaudhary	120	ND	96
Lila B. Pun	60	8	87
Bhanu Primary School	120	ND	96
		Average =	93

Georges Tabbal

Table 3: Arsenic Results of Arsenic-Biosand from Georges Tabbal

Contact person	**Total Arsenic Concentration by ITS Test Kit**		**% Removal**
	Raw ($\mu g/L$)	*Filtered ($\mu g/L$)*	
Ma Data Subede	400	15	96
Birbed Gurung	400	200	50
Rhada Chaudhary	300	5	98
Bhanumati Yadav	250	5	98
Siushagar Yadav	300	ND	98
Average =			88
Average without Birbed Gurung=			97.5

RWSSSP

Table 4: Arsenic Results of Arsenic-Biosand from RWSSSP

Contact person	**Total Arsenic Concentration by ENPHO Lab**		**% Removal**
	Raw (µg/L)	*Filtered (µg/L)*	
Ramashankar Yadav	377	24	94
Harilal Yadav	272	9	97
Nirahi Chaudhary	213	30	86
Tek Bahadur Hamal	848	5	99
Durga Kumari Subedi	936	12	99
Average =			95

6.2.2 THREE-KOLSHI

Georges Tabbal

Table 5: Arsenic Results of Three-Kolshi from Georges Tabbal

Contact person	**Total Arsenic Concentration by ITS Test Kit**		**% Removal**
	Raw (µg/L)	*Filtered (µg/L)*	
Shyam Kala Panthee	60	10	83
Nisha Bhushal	60	5	92
Average =			88

RWSSSP

Table 6: Arsenic Results of Three-Kolshi from RWSSSP

Contact person	**Total Arsenic Concentration by ITS Test Kit**		**% Removal**
	Raw (μg/L)	*Filtered (μg/L)*	
Punasi Tharu	50	ND	90
Mangai Tharu	50	ND	90
Lautan Tharu	50	ND	90
Sukhal Tharu	50	ND	90
Kedar Nath Chaudhary	50	ND	90
Khimal Bhattarai	60	ND	92
Thageshowar Bhattarai	60	ND	92
Average =			91

6.2.3 TWO-KOLSHI

Table 7: Arsenic Results of Two-Kolshi from ENPHO

Test Water ID	**Total Arsenic Concentration by ITS Test Kit**		**% Removal**
	Raw (μg/L)	*Filtered (μg/L)*	
1	91	17	81
2	95	13	87
3	97	11	88
4	221	9	96
5	197	17	91
6	198	13	94
7	277	16	94
8	276	22	92
9	274	21	92
Average =			91

6.3 FLOW RATES

The flow rate of the Three-Kolshi was measured extensively by ENPHO over the past two years as part of their pilot study to determine the effectiveness of this filer. The flow rate of the Arsenic-Biosand filter was measured by Tommy Ngai during his January 2003 trip to Nepal. He measured the flow rate using a stopwatch and a graduated cylinder. First, water is poured into the diffuser box to the top (i.e. water level at 25 cm above the outlet). He waits for 15 seconds to get a steady flow rate. Then, he times using his stopwatch how many seconds it takes to fill the graduated cylinder to 100 mL. He then divides 100ml by the amount of seconds he counted. Finally he converts this amount from ml/sec to L/hr. It should be noted that the flow rate of the filter is dependent on how much water is in the diffuser. The more water in the diffuser, the more hydrostatic pressure through the sand filter, and the faster the flow rate.

The flow rate results of the various filters can be found in Table 8. No information is currently available on the flow rate of the Two-Kolshi at this time.

Table 8: Flow rates of Filters

TYPE OF FILTER	RANGE OF FLOW RATES
Three-Kolshi	0.5 to 3L/hr
Arsenic-Biosand	10 to 20 L/hr

7.0 CREATION OF SURVEY INSTRUMENT

7.1 BACKGROUND RESEARCH

The background research that was conducted to create the survey instrument used in this study involved four components:

- A review of Knowledge, Attitudes and Practices (KAP) surveys;
- A review of Rapid Assessment (RA) surveys;
- A review of three previous M.Eng Theses;
- A description of the research plan of a currently undergoing project: “Evaluation of Ceramic Microfilter in Bolivia” conducted by Tom Clasen, affiliated with the London School of Hygiene and Tropical Medicine, with input from the Center for Disease Control and the Pan-American Health Organization.

7.1.1 KNOWLEDGE, ATTITUDES AND PRACTICES (KAP) SURVEYS

This method has been particularly popular in the 1960’s and 1970’s as a means for health-related research in gathering social data for large, statistically representative, populations. It seeks to measure cultural and behavioral variables as well as socio-economic ones (income, education, occupation, class…) that could be used in a health study. This type of survey is mainly quantitative, as it involves compiling all the survey results into statistical charts. It has proven to be efficient and appropriate in measuring socio-economic variables. However, there is increased awareness that it is inadequate to document behaviors and explain social opinions because it relies on quantitative analysis of qualitative research. This pitfall of the KAP survey was remediated by verifying survey data through the process of triangulation. Through this process, a whole range of factors is taken into consideration when analyzing the survey data. This lead to a new type of survey called the Rapid Assessment survey (RA). The name of the RA survey implies correctly that the survey is conducted over a short period of time. Although the KAP survey was not designed as a rapid assessment procedure, it was most often conducted rapidly, which might mislead people into considering it as an RA survey. However, these two types of surveys should be considered distinct.

7.1.2 RAPID ASSESMENTS SURVEYS

This type of survey, which be referred to as RA in this study, was developed to give a rapid social input in disease control programs. It was initially devised by disease control agencies such as the World Health Organization (WHO) to expediently get a whole range of social inputs necessary for their work. It involves the speeding up of social-science research, and the explicit linking of assessment to action, thereby giving priority to pragmatic rather than scientific outcomes (Rhodes, 1999).
In an RA survey, a multidisciplinary team is assembled to conduct the study. The team goes into the field for a short period of time, typically less than a month. In that time they conduct an intensive series of semi-structured, open-ended interviews, altering the direction or focus of the research as circumstances dictate (Paynter, 2001). The collected data are then analyzed in a qualitative manner, taking into consideration the many social and cultural factors that may dictate the subject's behavior (Paynter, 2001).

Manderson and Aaby (1992) subdivide RA surveys into the following types:

- Community Diagnosis: This type of RA surveys emphasizes "interaction with the community, an imperative to challenge both dominant (elite or expert) knowledge and understandings, and to translate technical knowledge to the community and community views to planners and decision-makers, to enhance dialogue and collaboration" (Manderson and Aaby, 1992). The main component of this type of survey is its participatory approach. A special emphasis of this approach is the use of local assistants to work with the surveyors to gather data.
- Rapid Epidemiological Assessments (REA): This type of survey was developed by the WHO as a consequence of the growing interest on the part of

epidemiologists to develop techniques which yielded highly reliable quantitative data, primarily for the paurpose of program evaluation. It can be perceived as a community diagnosis survey tailored to the needs of generating data that could be used in an epidemiology study.

- Rapid Rural Appraisal (RRA): Like the REA survey, the RRA survey can be seen as a community diagnosis survey that has been modified to accommodate the needs of a specific type of study, in this case agricultural studies. This method emphasizes the involvement of high-level multi-professional teams, including from agricultural, sociology, nutrition and others depending on the research question; a mix of methods depending on the research question; a mix of methods depending again on the subject of enquiry; the use of diverse source material; and the use of local knowledge and resources. Through these techniques of triangulation, and insistence on constant interaction between professionals to maximize the iterative process, the data generated has been represented as valid and relatively reliable (Manderson and Aaby, 1992).

7.1.3 M.ENG THESES

This section will review some of the relevant previous social acceptability and health-based studies of various household drinking water treatment interventions conducted by M.Eng students as part of their thesis work. These studies are as follows:

- Nathaniel Paynter, June 2001: "Household Water Use and Treatment Practices in Rural Nepal, Biosand Filter Evaluation and Considerations for Future Projects".
- Arun Varghese, June 2002: "Point-Of-Use Water Treatment Systems In Rural Haiti, Human Health And Water Quality Impact Assessment".
- Hannah Sullivan, June 2002: "Household Water Chlorination for the Developing World, A Case Study in Lumbini Nepal".

NATHANIEL PAYNTER

The purpose of Paynter's research was to investigate the appropriateness of the Biosand Filter in addition to identifying various considerations that should be taken into account when implementing a water treatment program. In order to achieve that objective he drafted a questionnaire and then traveled to Nepal in January 2001 to survey several households in the Terai. The background research section of his thesis was well done. As such, it constituted the main component of the background research that was conducted to draft the survey used in this study.

Paynter describes in his thesis the two basic types of survey that are traditionally used to acquire public health information in the developing world. These are: the questionnaire-based traditional sample oriented survey and the more flexible, interview-based survey. A brief overview of these two types of surveys is described below, alongside an explanation on why none of them is fully appropriate for his study.

Questionnaire Surveys

This type of survey is always rigidly constructed with little or no room for interpretation. Each question is strictly close-ended, and the responses are either in a multiple-choice format or scaled. The different responses are then compiled into statistical charts to provide accurate information on trends in health and population. This type of survey is especially appropriate for massive nation-wide surveys such as the Demographic and Health Surveys (DHS) conducted by the American firm Macro International (Paynter, 2001). A DHS typically involves tens of thousands of interviews, costs millions of dollars and focuses on population, maternal and child-health data. In this case the strict format of a questionnaire survey is necessary both for the traditional statistical analysis utilized and for the consistency across the several hundred evaluators conducting the survey.

By removing any room for interpretation by the interviewer, the strict format does not address the many un-quantifiable factors that may determine human perceptions of health issues. For example a typical question on a questionnaire type arsenic survey would be:

Do you know what arsenic is?

____YES **____NO**

A response to the above question may be, “yes it is a disease”. A questionnaire survey cannot handle such a situation. The strict format would not be able to reflect this person’s perception of what is the true nature of Arsenic and a valuable piece of information is in effect not taken into account in the study. Clearly, a survey of this type was not appropriate for the survey he was planning to conduct. His survey was much smaller, cheaper, shorter and more narrowly focused then a DHS.

<u>Interview-Based Surveys/ Rapid Assessment</u>

An interview-based survey has a less rigid format then the questionnaire-based survey. Although the surveyor starts the survey with a set of fixed questions, he is free to add, remove or change questions during the survey to accommodate the specificities of the respondent. A special subgroup of interview-based surveys is the Rapid Assessment (RA) survey. This type of survey seemed attractive to Paynter as it is cheaper and much more rapid than the questionnaire survey. Unlike the questionnaire survey, it gives the interviewer room for interpreting people’s answers. RA surveys are “construed with a view that different people perceive and understand reality differently, but in equally valid ways, and therefore the survey needs to reflect that”(Paynter, 2001). The fact that a multi-disciplinary team conducts this type of survey was especially attractive to him. However, since he was to conduct the survey by himself, this feature was obviously lost. Furthermore a one person-survey “team” will push the survey in a direction that will reflect the perceptions, judgments and values of that person. As such, he concluded “a one-person survey will have a larger negative impact in a RA survey then in a questionnaire survey” (Paynter, 2001).

Due to his reluctance of using exclusively one of these two methods, Paynter decided to combine them as he was in the field. His survey instrument originated as a KAP-style survey, before evolving into a RA/KAP hybrid. A detailed description of this type of survey is offered in section 7.2.3.

HANNAH SULLIVAN

Sullivan's thesis consisted of evaluating a household water chlorination pilot study in Lumbini, Nepal that was implemented by the Nepal Water Project team in January of 2001. The Center of Disease Control's Safe Water System Program was chosen as a model for this pilot treatment Program, because it represented a proven technology for household water treatment and had been successfully implemented in other regions of the developing world (Sullivan, 2002). The objectives of the CDC Safe Water Program are to "improve water quality in homes by means of a sustainable technology, to decrease death and diarrhea from contaminated drinking water, and to improve hygienic behaviors related to water use (Sullivan, 2002). The Program has three key components:

- Point-of-use treatment of contaminated water using locally produced sodium hypochlorite solutions (NaOCl).
- Safe water storage in containers.
- Education campaign designed to teach the population about adequate treatment and storage techniques as well as to increase basic awareness of the benefits of safe water.

The pilot study design called for the inclusion of an intervention group consisting of 50 families and 10 schools that would receive the chlorine solution and a modified bucket system for household water storage practices and a control group consisting of 50 families and 10 schools that would continue with their traditional water collection and storage practices (Sullivan, 2002). A local organization, the International Buddhist Society (IBS), was put in charge of continuously monitoring the Program. The major components of this monitoring plan were bi-weekly water testing, and bimonthly health program reports.

Sullivan traveled to Nepal in January of 2002 to complete a thorough field investigation of the pilot Program and make recommendations for its expansion or discontinuation. There were five aspects to this field evaluation, four of which were technical and one was social.

Technical Evaluation

- Historic Health and Microbial Data Review (Baseline): The records of the local NGO (International Buddhist Society) in charge of monitoring the pilot study were collected. These records included health survey data and microbial testing results
- Source Water Testing: All the wells of the Lumbini region were tested for microbial contamination.
- Verification of Raw Water and Chlorine Treated Water: Water samples were collected from the households participating in the pilot study during unannounced visits. These samples were tested for bacterial contamination and free chlorine residuals.
- Chlorine Dose: Tests were conducted to determine if the recommended dose of chlorine disinfectant was adequate to treat the local water.

Social Evaluation

A household survey was conducted to observe household water storage and chlorination practices, to evaluate the social acceptability of household chlorination in Lumbini and to determine if villages perceived any changes in their health due to the chlorination project (Sullivan)

Only the fifth aspect of Sullivan's evaluation, the social evaluation, was found to be relevant to the social acceptability study to be conducted by the author. Sullivan's household survey consisted of three main parts:

- Water Chlorination, Handling and Consumption Practices: In this section the respondent was asked about his or her chlorination practices such as the amount of disinfectant he or she is using. The respondent was also asked about broader water practices such as the type of water consumed outside the home or the frequency of hand washing.

- Project Acceptance-Social Acceptability of Chlorination: The purpose of this part of the survey was to evaluate the respondent's acceptance of chlorination as a mean of cleaning his or her water. The respondent was asked questions such as: "Do you find the disinfection process difficult?" or "How do you feel about the taste and smell of the disinfected water?"
- Perceived Health Effects: The purpose of this section was to evaluate whether the introduction of disinfection into the household has reduced the incidence of diarrhea among its members.

ARUN VARGHESE

This thesis written by Arun Varghese (Varghese, 2002) assessed the health and water quality impact of a chlorine-based purifier system implemented in rural Haiti by an NGO by the name of Gift of Water Inc.

The water quality impact assessment study was the technical component of this thesis and consisted of measuring the microbial removal rate of the system by using membrane filtration tests.

The health impact assessment study was the social component of his thesis and was conducted by administering a questionnaire to a hundred and twenty households in the villager of Dumay. The questionnaire consisted of thirty questions, twenty of which were multiple-choice while the rest were open-ended. The questionnaire was intended to gather data on some measurable variables that were likely correlated with health outcomes. These variables include: Household size, quality of housing, occupation, religion, filter use characteristics etc…

Univariate, bivariate and multivariate statistical methods were then used to impact of the water treatment system in reducing the incidence of diarrhea, after controlling for socio-economic differences in the population (Varghese, 2002). The univariate analysis consisted of simply compiling the variables into statistical charts. These descriptive statistics were used to get a preliminary picture of the demographic features and behavioral characteristics of the population. The bivariate analysis sought to establish whether there were differences in the mean values of particular variables between groups of interest in the population. For instance a bivariate analysis was used to compare the incidence of diarrhea in groups with and without filters, not controlling for any other variables. The multi-variate analysis was the culmination of the previous analyses. It consisted of creating a model to explain health outcomes in terms of relevant explanatory variables. This was achieved by fitting an equation (health outcome) to the data (variables). Regression is the process of fitting an equation to this data. Three types of regression methods were used in this study: least squares, logistic and probabilistic. The multi-variate analysis allowed Varghese to obtain the incidence of diarrhea while taking into account numerous simultaneous variables. This analysis allowed him to get more representative results then the bivariate analysis, which could only handle one variable.

7.1.4 RESEARCH PLAN OF "EVALUATION OF CERAMIC MIRCOFILTER IN BOLIVIA"

This Plan is being implemented from January 2003 to July 2003 under the coordination of Thomas Clasen, JD, MSc who is affiliated with The London School of Hygiene & Tropical Medicine. Fundacion Sumaj Huasi, a Bolivian NGO with extensive experience in water and sanitation, has agreed to implement the Plan in the community of Charinco in Bolivia. Its objective is to examine the effectiveness of the Doulton ceramic mircofilter (produced by Fairey Industrial Ceramics, Ltd.,) as an alternative to the Safe Water System. The research objectives can be summarized in four categories:

- Social Acceptability: Determine the social acceptability of the Doulton filter by household surveys;
- Technical: Measure the effectiveness of the water filter system in improving water quality at the household level;
- Health: Assess the impact of the filter system on reducing diarrhoeal disease;

- <u>Economic</u>: Determine affordability through a willingness-to-pay study (Clasen Thomas, 2003).

The first study is the one that is the most closely related to the study conducted by the author. Thomas Clasen refers to it as a "longitudinal study" and its purpose is to evaluate: 1) the acceptability of the filters among the study population; 2) the performance of the filters in improving water quality during household use; 3) affordability of the system to the target population, and 4) health impact. In order to achieve these objectives, the "longitudinal study" will be conducted in the following steps:

- The head of each household is interviewed about family demographics, family wealth, water source, water handling practices and knowledge of diarrhoea prevention.
- Village households are then assigned into two groups: an intervention group and a non-intervention group. The intervention group will receive filters and the non-intervention group will still use the traditional water treatment and storage practices.
- Each month during the six-month period after the distribution of the filters, all homes will be visited to assess use of the filters in the intervention households and water quality in all households.
- Data will be entered into Epi Info software. Data will be analyzed descriptively to determine the proportion of the intervention households using the Doulton filters correctly. Data will also be analyzed to determine differences in the microbiologic quality of stored water between intervention and control households.

7.2 SYNTHESIS OF BACKGROUND RESEARCH

This section will provide the reader with a synthesis of all the different social studies described in the previous sections as well as their relative relevance to the author's study.

Studies using similar techniques will be regrouped together in an attempt to synthesize for the reader all the different survey techniques used in these studies.

7.2.1 QUESTIONNAIRE-BASED SURVEYS

As stated in section 7.1.4, the questionnaire-based survey is rigidly constructed. Each question is strictly close-ended, and the responses are either in a multiple-choice format or scaled. The different responses are then compiled into statistical charts to provide accurate information on trends in health and population. It is the author's belief that the KAP survey, Varghese's survey and Sullivan's survey can all be characterized as questionnaire-based. However, these can be further differentiated by the manner the data collected is analysed. Questionnaire surveys can therefore be sub-divided into two groups: univariate analysis of results and multi-variate analysis of results.

Univariate Analysis of Results

This type of result analysis was the one used by Sullivan and the one advanced by the KAP survey. The univariate analysis consists of simply compiling the variables measured through the survey (household income, instances of diarrhea within a household etc…) into statistical charts. These charts are then used to get an assessment of the behavioral characteristics of the population (level of arsenic awareness, water contamination awareness etc…). This simple method of result analysis is especially attractive to studies where the social component is minimal, such as Sullivan's. It can provide, with a minimal amount of time and effort, a picture of some behavioral characteristics of the population. However it is inadequate in providing an accurate evaluation of these characteristics because it relies on a one-dimensional quantitative analysis of qualitative research. An obvious improvement of this method is to change it into a multi-dimensional quantitative analysis. This can be achieved through a multi-variate analysis.

Multi-Variate Analysis of Results

This is the method used by Varghese to analyze his results and draw conclusions on the behavioral characteristics of his surveyed population. The multi-variate analysis allows

the surveyor to assess how a specific behavioral characteristic, for example, the level of arsenic awareness, can change while changing numerous variables simultaneously, such as household income, ethic group, religion etc.
The Bolivian Ceramic Microfilter research study relies on a form of multi-variate analyis, called bivariate analyis to evaluate the data. The bivariate analysis allows the surveyor to assess how a specific behavioral characteristic can change while changing only one variable. The researchers in that study will determine differences in the microbiologic quality of stored water (characteristic) between intervention and non-intervention households (variable).

Although the multi-variate analyis method is much more accurate then the univariate one, it is time-consuming. As such, it should only be used in studies where the social component is prominent over the technical one, like the one conducted by the author.

Varghese's highly statistical type of analysis was attractive to me. It would have allowed me to examine the effect of multiple simultaneous variables on the arsenic and filter awareness of the surveyed population. In Varghese's terms, my actual data analysis of my survey results (variables) was purely univariate, and as such not very representative. Unfortunately his work came to my attention after I came back from Nepal, which did not give enough time to conduct a bivariate or multivariate analysis.

7.2.2 INTERVIEW-BASED SURVEYS

An interview-based survey has a less rigid format then the questionnaire-based survey. Although the surveyor starts the survey with a set of fixed questions, he is free to alter the survey instrument during the survey to accommodate the specificities of the respondent. A specific type of interview-base survey is the Rapid Assessment (RA) survey, which relies heavily on a process of triangulation to verify the survey data. Through this process, a whole range of factors is taken into consideration when creating the survey instrument and analyzing the survey data. Some of this factors include: the involvement of high-level multi-professional teams, a mix of methods depending on the research question, a mix of methods depending again on the subject of enquiry, the use of diverse source material, and the use of local knowledge and resources.

For an arsenic study like the one conducted here, an ideal team to conduct an RA survey might have included a hydrologist, a sociologist, a water quality engineer, a public health specialist and translators, among others. In the context of this study, the main strength of the RA survey is that it allows the interviewers to come up with assessments while they are still in the field. As such they can alter their survey format in the field to make it more relevant to the study they are conducting. This is especially important when conducting a survey in an area that one knows very little about. My social acceptability survey of three different arsenic removal was conducted in some of the poorest villages of rural Nepal, an environment that the interviewer of this study knew almost nothing about. As such, an RA format was especially appealing for this study because of its rapid and flexible aspects.

However, the RA surveys method was not completely adequate for my arsenic study. Multi-disciplinary teams typically conduct RA surveys, which was impossible in this study as one non-native interviewer with the help of a translator conducted it. The most attractive feature of an RA survey, namely the ability to get a wide range of inputs from people of varied backgrounds within the team, is therefore lost. Furthermore, a one person-survey, plus a translator, will push the survey in a direction that will reflect the perceptions, judgments and values of that person.

7.2.3 MIXTURE OF INTERVIEW AND QUESTIONNAIRE-BASED SURVEYS

The type of survey instrument used by Nathaniel Paynter can best be described as a mixture of Questionnaire and Interview-Based surveys. The original survey instrument that he devised prior to his trip to Nepal was strictly a questionnaire type of survey, most specifically a KAP survey. Furthermore he planned on analyzing his results by the univariate method of analysis. As he conducted his survey in the field, he altered his survey to reflect some characteristics of the surveyed population that he did not foresee prior to his arrival to Nepal. This modification of the survey instrument is not allowed in a KAP survey and is a characteristic of an RA survey. As such, his survey instrument evolved into something he called a KAP/RA hybrid as he kept some questions from the original instrument and modified others during the course of his site visit.

This unconventional type of survey instrument was attractive to me prior to my site visit to Nepal. It allows the surveyor of devising an original survey instrument by using the limited knowledge that he has about the surveyed population prior to his site visit. As he conducts his survey in the field, his knowledge of the population increases, and as such he is free to alter this survey instrument to reflect this new knowledge. Section 7.3 of this report will describe how, like Paynter, my survey evolved from a KAP type to a KAP/RA hybrid.

7.3 CREATION OF SURVEY INSTRUMENT

As explained in the previous section, the original survey instrument devised before the site visit was of the KAP format as most of the questions were multiple-choice and only a few were open-ended. The structure of the survey instrument was inspired from the instrument used by Nathaniel Paynter in his thesis. Paynter, himself, inspired himself from a survey instrument used by Jennifer Davis, an MIT Urban Studies professor with extensive experience in surveys with USAID.
The questions that didn't require much interpretation of their answers were drafted with a multiple-choice format. As such, the answers would be compiled into statistical charts, which could be used to determine trends within the sample population. The more subtle questions were left in an open-ended format, which can allow the interviewer to interpret the answers and improve the survey instrument as he goes along. As explained in section 7.2.3 the survey instrument evolved into a KAP/RA hybrid as more and more open-ended questions were added. This evolving process is explained in detail in section 7.3.1.

As soon as I arrived to Butwal, I had the survey instrument translated into Nepali to facilitate the job of the translators assigned to my study. Unfortunately, for the first few days of the survey, the translator assigned to the study was not fluent in English. As such he would only be able to translate back to me the answers to multiple-choice questions, as these answers were written in Nepali on the translated questionnaire. Most of the answers to the open-ended questions were more complicated, and therefore beyond the ability of the translator to convey them to me in English. The survey instrument was therefore compelled to be of the questionnaire type for the first few days. A better translator was assigned for the following week, which allowed the survey instrument to gain some RA components. An excellent translator joined the team for the last three days, therefore producing the best results of the trip. Nevertheless, as soon as the second translator was assigned, the survey instrument started changing shape as anticipated. An overview of the original survey and the final survey is offered below. These survey instruments can be found in Appendix I and II of this report. The reader will better understand the following two sections after reading the Appendices.

7.3.1 ORIGINAL SURVEY INSTRUMENT

The original survey devised in the fall semester at MIT was broken into 3 main sections: Background, Water Quality and Filters.

Background

The purpose of this section was to lay the groundwork for understanding the perspective of the respondent. It consisted of noting the caste, ethnicity, gender and age of the respondents as well as the number of people in their households.

The NGO's on the ground, namely RWSSSP and Japan/Nepal Red Cross distributed one filter per affected household. Since some households are bigger than others, it was necessary to evaluate whether one filter was sufficient for the bigger families. Respondents were therefore asked about the number of people in their households to help determine the service 'cut-off' point of each type of filter.

Water Quality

This section was intended for 2 main purposes: to evaluate the perception of the respondent on arsenic related issues and to examine the water practices of the respondent. The first three questions were intended to evaluate the current knowledge of the respondent on arsenic in general and on any arsenic contaminations in his water source. These questions proved to be insufficient in the first few days of the survey and they were reworked (see Section 7.2.3).

The next 3 questions of the section consisted of determining the occurence of arsenicosis in the visited villages by asking the respondents about any arsenicosis symptoms either in that respondent or anyone in his or her household or village.

The last five questions of the section examined the water practices of the respondent and his or her household. These were useful in determining the main source of drinking water of each household and the distance to the source. As expected the question: "How much water does your household use on a daily basis" proved to be difficult to answer, as most people were not familiar with units of volume. People were then asked about how many kolshis did they use every day and then asked to show us the kolshi. My translators would then give me an approximate volume of the kolshi, which would allow me to get an idea about the daily water consumption.

<u>Filters</u>

This section was designed to be the bulk of the survey. It was intended to examine the respondent's perception on using arsenic filters. For those respondents who already owned filters, it was also intended to examine their perception on the type of filter they were using.

The first question on the type of arsenic filter currently being used had four possible answers: none, Three-Kolshi, Two-Kolshi and Arsenic-Biosand. The survey will branch out in a different direction depending on the answer of the respondent.

<u>*For none*</u>

If the respondents answers by none, he will have to be subjected to a line of questioning to determine his willingness to acquire an arsenic filter. Questions cover willingness-to-pay, readiness to put in a certain amount of work to operate the filter and perception on usefulness of acquiring the filter. This line of questioning proved to be irrelevant and had to be completely eliminated from the survey. A thorough well testing operation had been conducted in the past years by RWSSSP in the districts under its jurisdiction. In the four months prior to the January visit filters had been distributed to all the households using wells that had tested positive for arsenic. As such, all the households that were visited in the January trip had been owning and operating a filter for the past four months.

For any filter

This section was intended to examine the perception of the respondents on the filters they were using. Since some questions generically applied to whatever filter one was using, these questions were regrouped in this section of the survey instrument. Generic filter questions that were specific for a certain type of filter were regrouped in separate sections for each type.

Questions covered satisfaction with flow rate, amount of work required to operate the filter, health improvements associated with filter use and filtering practices. The original survey included asking respondents if they thought the capital costs and operation and maintenance costs associated with the filter were too high. When I drafted these questions in Cambridge I didn't know that all the filters had been distributed free of charge by the NGO's on the ground. As such, these questions were irrelevant and were eliminated.

The section ends with the following open-ended question: "Do you have any complaint or recommendation that you would like to share about this filter". This question was included to get any input from the respondent that couldn't have been grasped from the earlier questions. It was also intended to possibly push the survey in a different direction then the originally designed one. For example, when a good portion of the respondents had complained about the tap of the Two-Kolshi filter, a question about it was included in the Two-Kolshi section of the revised survey.

For Two-Kolshi

The questions in this section were intended to address specific problems that might arise from using a Two-Kolshi filter. In Cambridge I was left under the impression that most Two-Kolshi users were having trouble obtaining the ferric chloride tablets necessary for its operation. I therefore included a question on this matter to determine whether or not the villagers were having any trouble acquiring these tablets manufactured in far away Katmandu. I learned when I got to Nepal that the various NGO's on the ground were doing an excellent job at tablet distribution. The question therefore appeared irrelevant, especially because the question was often asked after the technician accompanying me had handed over a fresh tablet to the respondent.

Since the operation of the Two-Kolshi filter was by far the most complicated of the three, I included the question: "Are you following ENPHO's directives exactly when filtering the water". Although I did not included it in writing, the question was supposed to be followed by an exact reminder of what these directives were.

For Three-Kolshi and Biosand

As the operation of these two filters was fairly similar, I included them in the same section, which had only on question: "How often do you clean the filer". This is especially important for these two filters, as they had been found to clog quite rapidly in laboratory conditions. Getting an idea on how often people clean them will help determine whether they are working at full capacity or not.

7.3.2 REVISED SURVEY INSTRUMENT

The revised survey instrument consisted of the main three parts as the original questionnaire. The content of each part, however, was altered as explained below.

Background

The first two questions, caste and ethnicity, were dropped on the first day of the survey due to the reluctance of the translators to ask the respondents about them. These were not considered to be crucial by them, as they didn't regard the caste and ethnicity of a respondent as determining factors of his or her perception on health and water quality matters.

Water Quality

A few days into the survey, the author decided to add a new question right after question two, “Do you know what arsenic is?” If the respondent answered by yes, he was challenged to define arsenic by asking him: What is arsenic?
Questions four to six, intended to evaluate the spread of arsenicosis in the visited villages, were eliminated from the questionnaire. This line of questioning was found to be unnecessary as the arsenic technicians who accompanied me had done an extensive health survey of the visited villages a few months earlier. As such, they knew the arsenic patients of all the visited villages and pointed them to me as we carried on our visits.

Filters

This part was mainly untouched by the revision of the survey questionnaire. The only change undertaken consisted of asking the willingness-to-pay questions (questions six and seven) to all people owning a filter. When the author drafted the original survey questionnaire in Cambridge, he was not aware that all the filters had been distributed for free. As such, he thought that a willingness-to-pay question would only be appropriate to people who have not acquired a filter yet. As it turns out, all the visited villagers fell in that category because although they all posses a filter, they never actually bought it.

8.0 SURVEY RESULTS

8.1 BACKGROUND SECTION

During the course of the survey, 54 houses were visited in the Nawalparasi, Rupendehi and Kapilvastu districts. The geographical distribution of these surveys, as well as the type of filter that was investigated in each VDC are summarized in Table 9.

Table 9: Geographical Distribution of surveys

DATE OF SURVEY	DISTRICT	VDC	NUMBER OF SURVEYS	TYPE OF FILTER
January 6	Rupandehi	Devdaha	5	Arsenic-Biosand
January 7	Kapilvastu	Barkalpur	6	Three-Kolshi
January 8	Nawalparasi	Sunwal	4	Two-Kolshi
January 10	Nawalparasi	Sunwal	7	Two-Kolshi
January 12	Nawalparasi	Sarawal	3	Arsenic-Biosand
January 13	Kapilvastu	Dubiya	4	Three-Kolshi
January 14	Nawalparasi	Panchangar	8	Three-Kolshi
January 15	Nawalparasi	Panchangar	5	Arsenic-Biosand
January 16	Nawalparasi	Sarawal	4	Arsenic-Biosand
January 17	Nawalparasi	Panchangar	8	Two-Kolshi
TOTAL			54	

Figure 13: Number and percentage of households surveyed for each type of filter

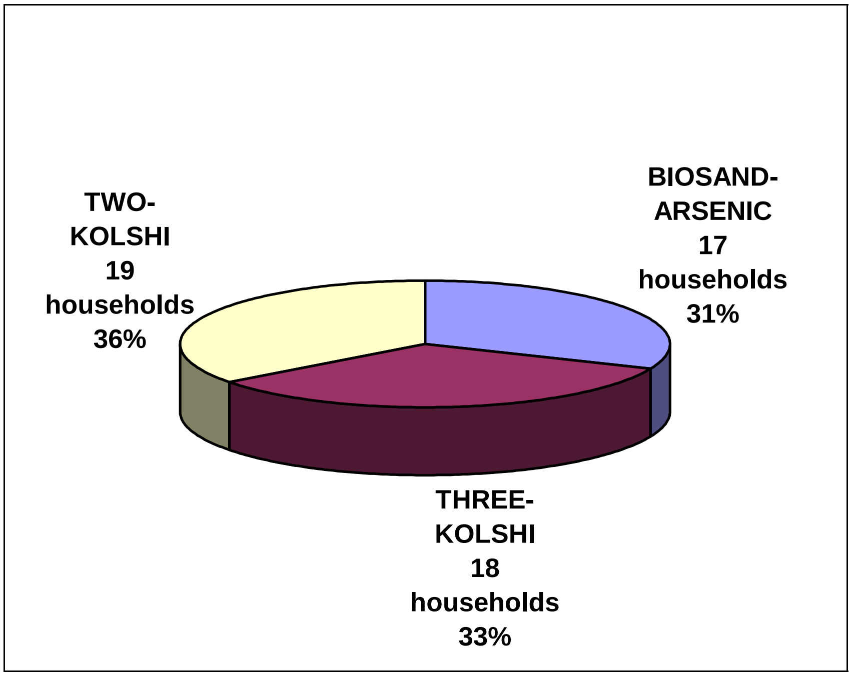
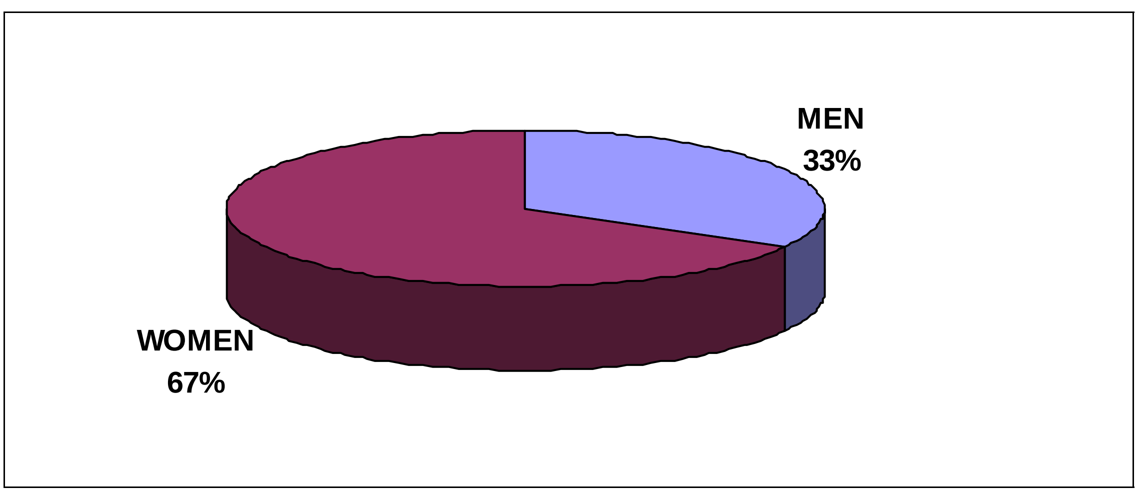


Figure 13 shows the number and percentage of households surveyed for each type of filter. A third of the visited filters were Three-Kolshis while 31% were Arsenic-Biosand filters and 36% were Two-Kolshis.

Figure 14: Distribution of surveys per gender



The discrepancy between the number of males surveyed and the number of females surveyed may be explained by the fact that the surveys were conducted between 11 am and 4 pm. During this time period, most of the men were at work, either in the fields or elsewhere.

The average number of people living in a single household was found to be about 8. The calculated standard deviation for the sample population of 54 households was found to be 4.8. It can therefore be inferred that two thirds of the visited households have between three and thirteen people living in them. Only 8 of the visited households had over 13 members. These households were scattered across the visited areas except in Dubiya, Kapilvastu where the households seemed to be of considerable size. The numbers of people living in the 3 surveyed households of Dubiya were: 20, 17 and 20. This might suggest that the Tharu villagers inhabiting Dubiya have much bigger households than their Nepali counterparts in the other visited villages.

Figure 15: How many people are there in your household?(54 respondents)

AVERAGE	8.0
STANDARD DEVIATION	4.8
HIGHEST NUMBER	22
LOWEST NUMBER	3

8.2 WATER QUALITY

8.2.1 WATER COLLECTION PRACTICES

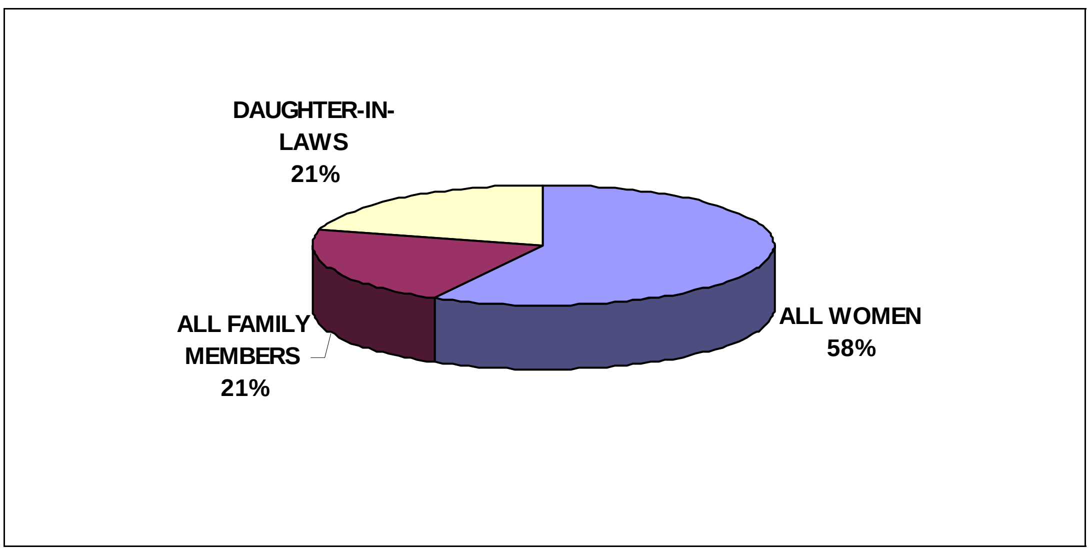
As explained in the previous section, the question “What is your household’s main source of drinking water?” was found to be irrelevant as all the respondents used a public tubewell with hand pump. However, the respondents were still asked about the distance of the main source of drinking water, namely the closest tubewell, from their household. The average distance for the 47 villagers who answered that question was found to be 5.4

m. The standard deviation was of 7.5 m, which means that about two thirds of the respondents had their main source of drinking water between 0 m and 13 m from their household.

Figure 16: How far from your household is your main source of drinking water? (47 respondents)

AVERAGE	5.4 m
STANDARD DEVIATION	7.5 m
HIGHEST NUMBER	30 m
LOWEST NUMBER	1 m

Figure 17: Who collects the water for your household? (54 respondents)



As stated earlier, most of the survey respondents were women. The response "all family members" to the question "Who collects the water for your household?" came in majority from the 18 males surveyed. A total of 11 people gave that answer, 6 of whom were males and therefore representing 54 % of the total people who volunteered that answer. This proportion of male is more than double the total male proportion of 21 % for the whole sample population. As such it is very probable that some males are in fact pretending to do the water collection, while it is the women who are actually doing it.

8.2.2 ARSENIC AWARENESS

Figure 18: Do you know what arsenic is? (54 respondents)

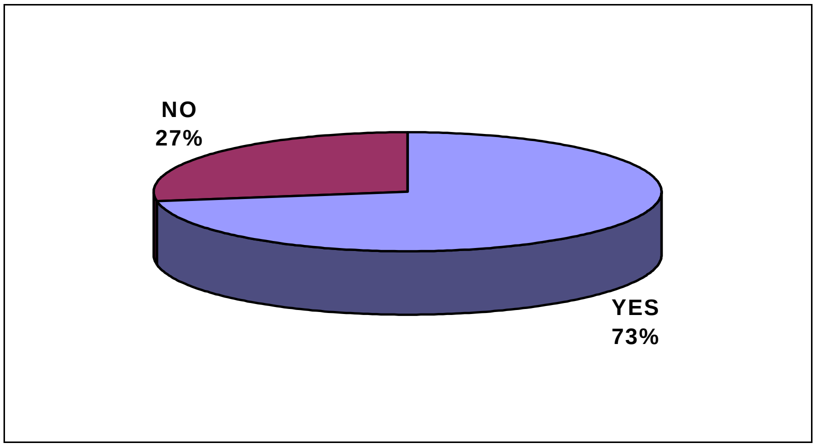
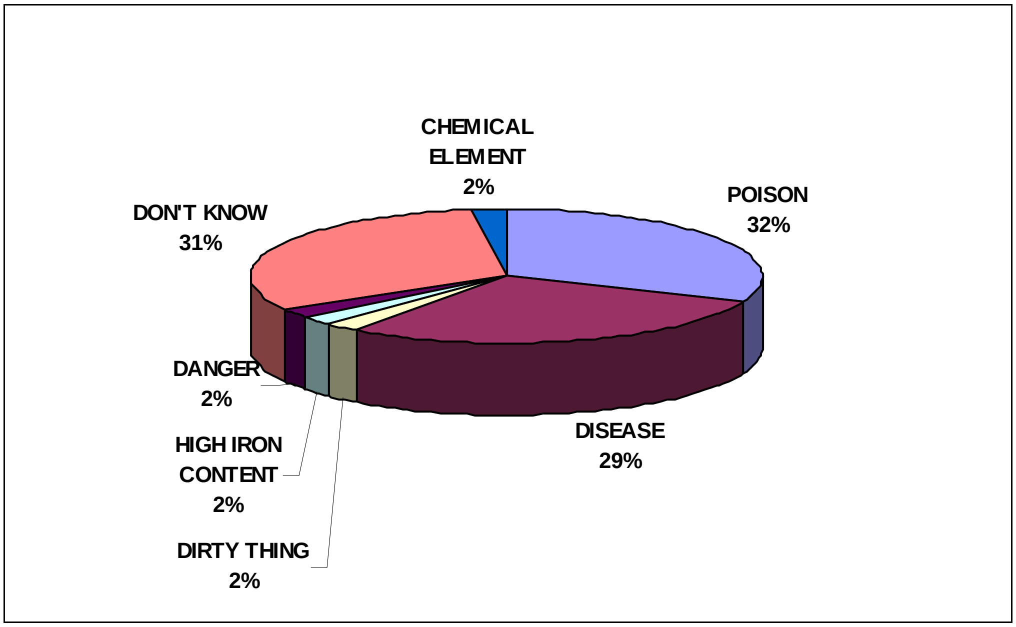
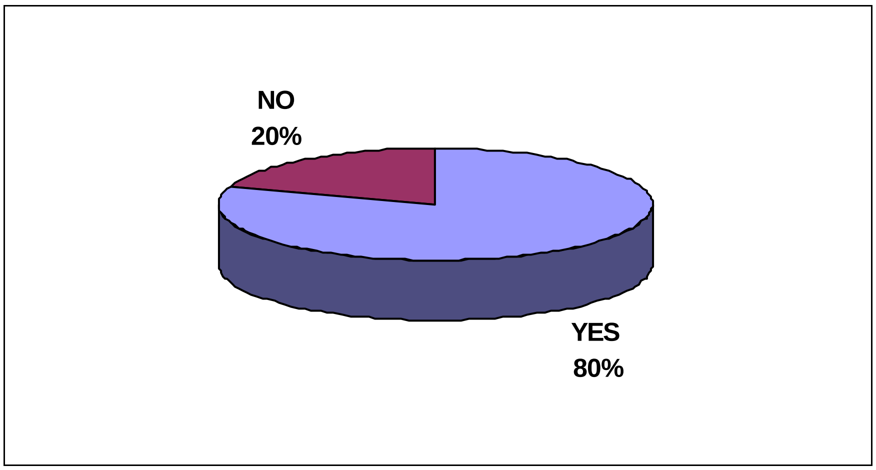


Figure 19: What is arsenic? (45 respondents)



A large portion of the respondents (45 respondents representing 73 %) claimed to know what arsenic was (see Figure 18). This high statistic became apparent very early on in the survey. As such, the subsequent 45 respondents were put to the challenge of explaining what they thought arsenic was (see Figure 19). Roughly, a third of them said that it was a poison, another third a disease and a final third did not know. This means that two thirds of the respondents associated arsenic with a health hazard, namely those who gave the answers “disease”, “danger” and “poison”.

Figure 20: Are you aware of any arsenic contamination in your water? (54 respondents)



About 20 % of the respondents were not aware of any arsenic contamination in their drinking water (see Figure 20). As stated earlier in this report all of the respondents were getting their drinking water from arsenic-positive wells. There is an obvious discrepancy between Figure 18 and Figure 20. Figure 18 shows that 27 % of the 54 respondents did not know what arsenic was while Figure 20 shows that only 20 % of those same respondents were not aware of any arsenic contamination in their drinking water. One might sumise that there are some villagers who never heard of arsenic but for some reason know of its existence in their water supply. The actual reason is that the villagers were asked the question corresponding to Figure 18 before they were asked the one corresponding to Figure 20. When some of the villagers answered that they did not know what arsenic was, they were subjected to a long arsenic awareness talk by the technicians who accompanied the author. As such when the villagers were asked the next question, not surprisingly they most often claimed that they were aware of an arsenic contamination in their drinking water.

Figure 21: Do you see any correlation between removing arsenic and protecting your health? (54 respondents)

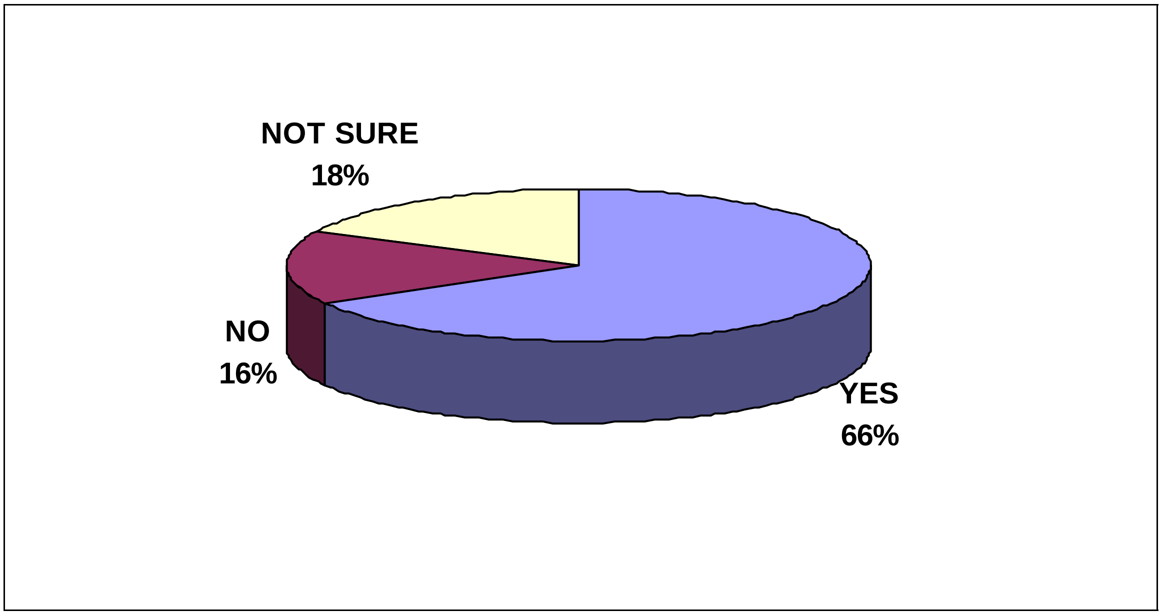
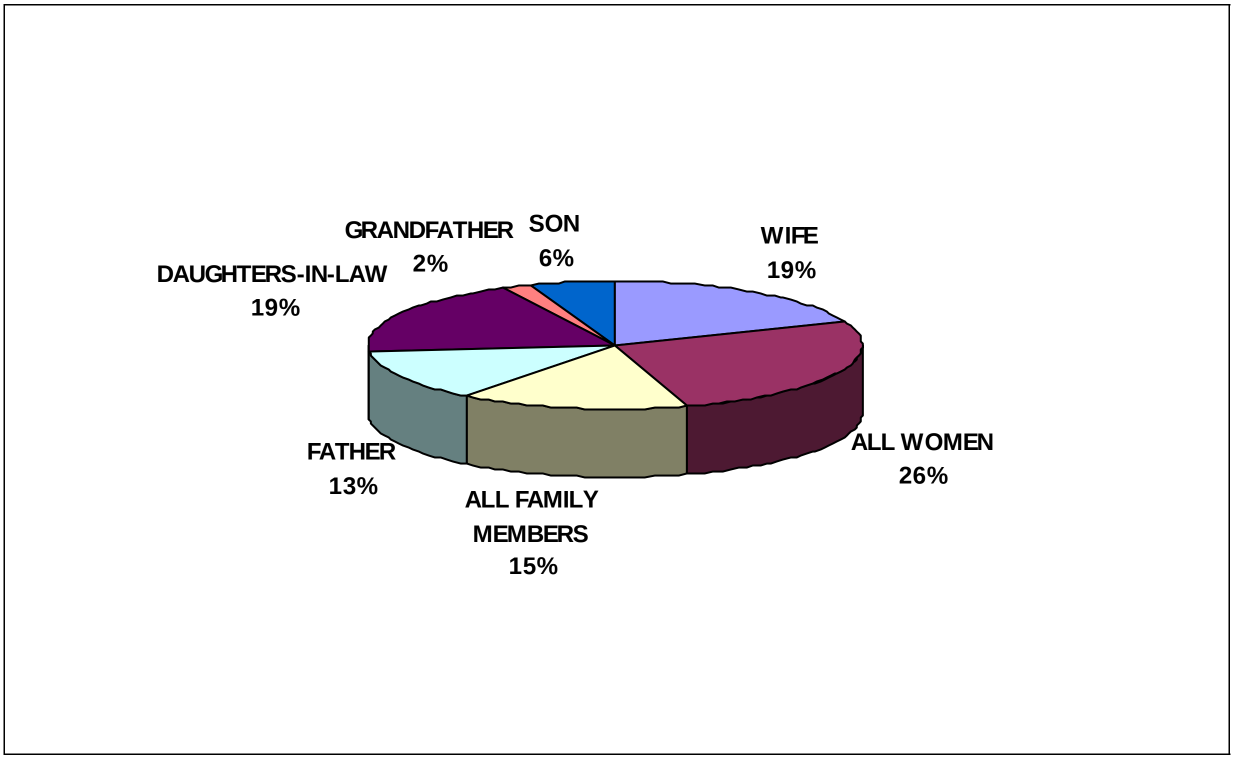


Figure 21 shows that 66 % of respondents answered by “yes” to the question “Do you see any correlation between removing arsenic and protecting your health?” while 16 % said no and 18 % said they were not sure.

8.3 FILTERS

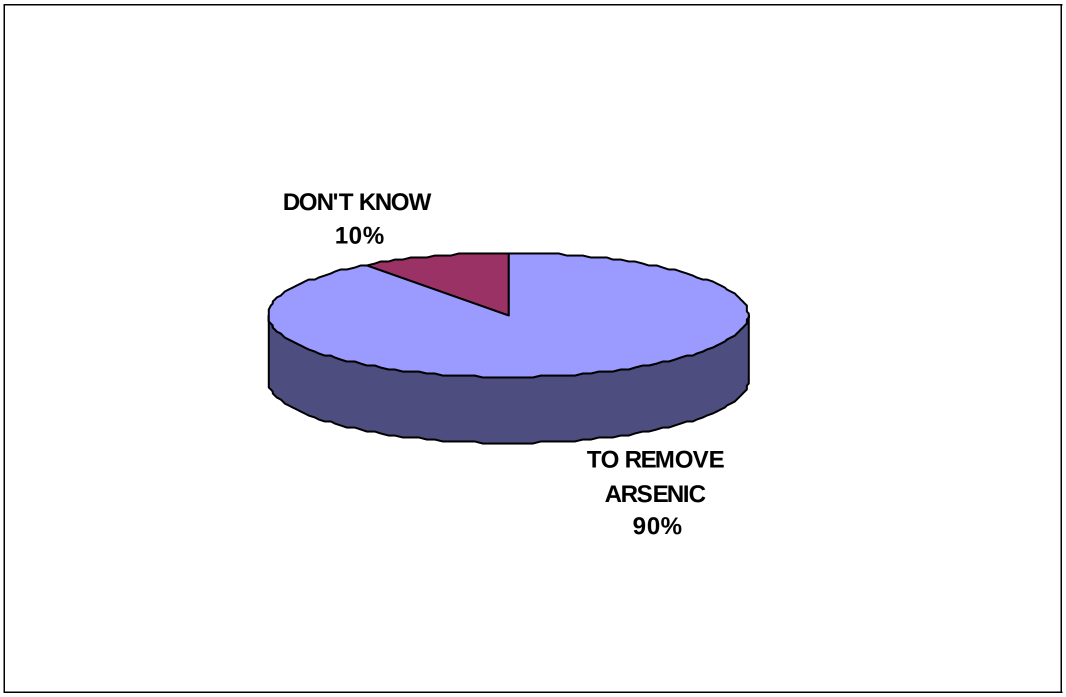
8.3.1 FOR ANY FILTER

Figure 22: Who cleans the filter in your household? (53 respondents)



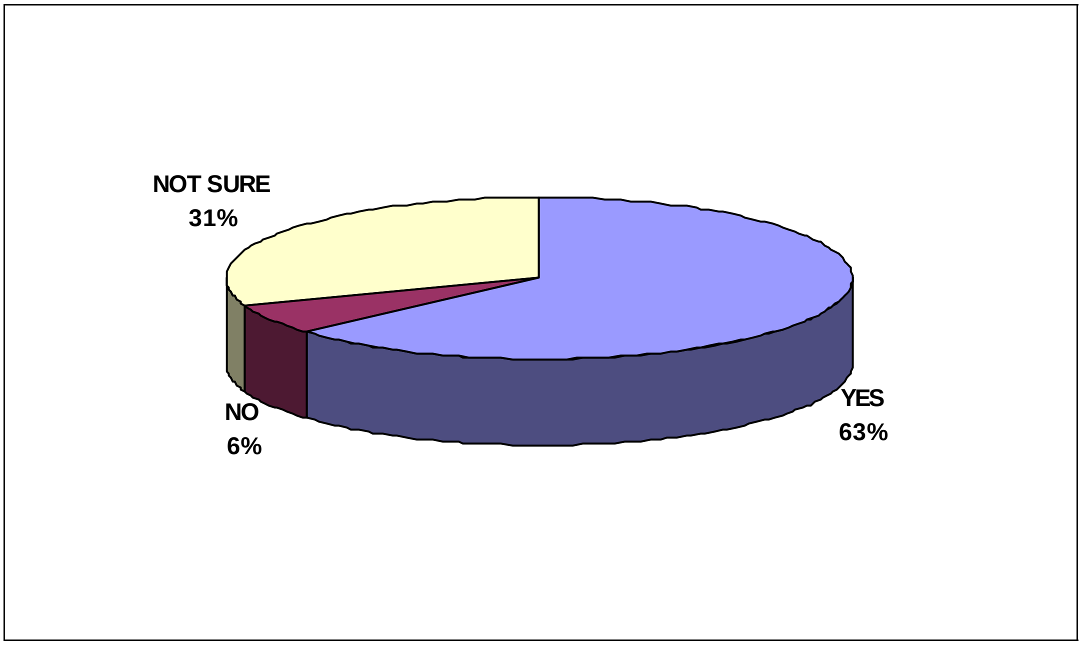
The answers to the previous question are very diverse, yet, as with water collection, the women seem to do the lion's share of the job. 63 % of the respondents affirm that the filter cleaning is done exclusively by women (wives, daughters-in-law or all women). It should be noted that 15 % of the respondents said that all family members undertake this task. This would mean that the women's share of the task is actually higher than 63 %. Twenty-one percent of the respondents attribute the task exclusively to males.

Figure 23: Why do you treat the water? (52 respondents)



Ninety percent of the respondents affirmed that they treated their water to remove arsenic. This very encouraging statistics might mislead the reader into drawing very optimistic conclusions about the level of arsenic awareness of the surveyed villagers. This number does not flow naturally from the less encouraging statistics stated earlier in this report. Figure 18 showed us that 27% of the respondents did not know what arsenic was and Figure 20 showed us that 20% of them were not aware of any arsenic contamination in their drinking water. The reason behind this inconsistency of results has already been explained. When villagers affirmed that they didn't know what arsenic was, the technicians defined it to them. As such when the villagers were asked the next question, they most often claimed that they were aware of an arsenic contamination in their drinking water. Those who affirmed that they were not aware of any arsenic contamination were yet subjected to another talk. As such, by the time the respondents were asked to state why they treated the water, they knew for certain what the surveyor wanted to hear: "I treat the water to remove arsenic".

Figure 24: Do you think the filter is protecting your health? (54 respondents)



8.3.2 ARSENIC-BIOSAND

Figure 25: Are you satisfied with the flow rate of the filter? (14 respondents)

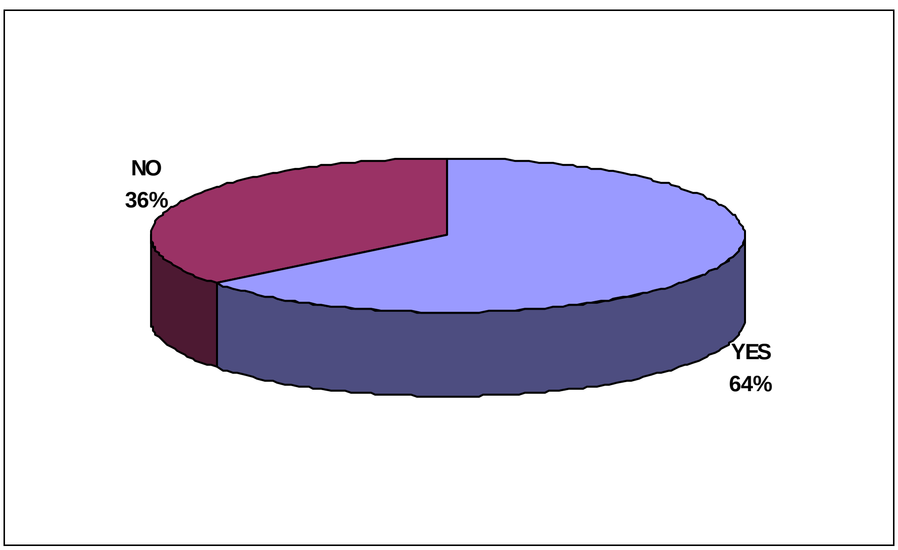
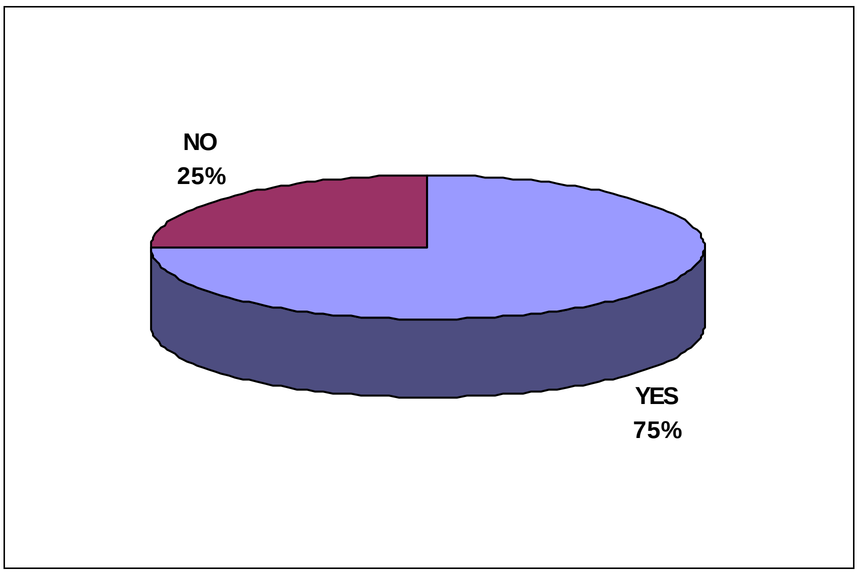


Figure 25 shows that 36 % of the respondents are not satisfied with the flow rate of the Arsenic-Biosand filter. This statistics might be surprising to the reader as the Arsenic-

Biosand filter has a high enough flow rate to accommodate a normal sized Nepali family (10-20 L/hr). The proportion of 36 % might be overstated due to the fact that two surveyed households are each sharing 2 filters with 2 other households. The flow rate of these 2 filters is not high enough to accommodate all 4 households currently using them. As such this statistic might be misleading and it would be more useful to drop those two households from the survey when compiling the answers to the flow rate question. The modified pie chart is given below as Figure 26.

Figure 26: Are you satisfied with the flow rate of the filter (12 respondents)?



The revised pie chart gives results that are probably more representative than Figure 25. It shows that 75 % of the respondents are satisfied with the flow rate of the Arsenic-Biosand filter.

Figure 27: Do you think that operating the filter requires too much work (13 respondents)?

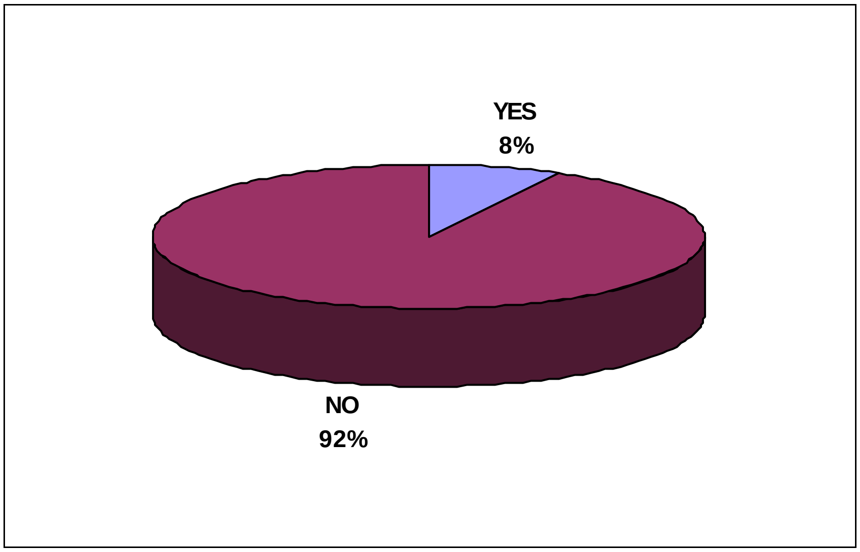


Figure 27 below shows that only 8% of the respondents think that operating the filter requires too much work.

Figure 28: How often do you skip filtration (12 respondents)?

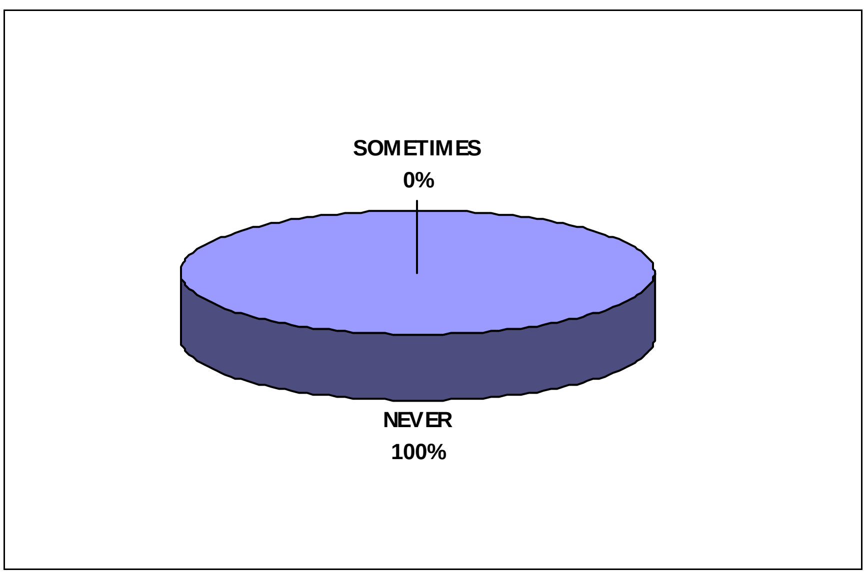
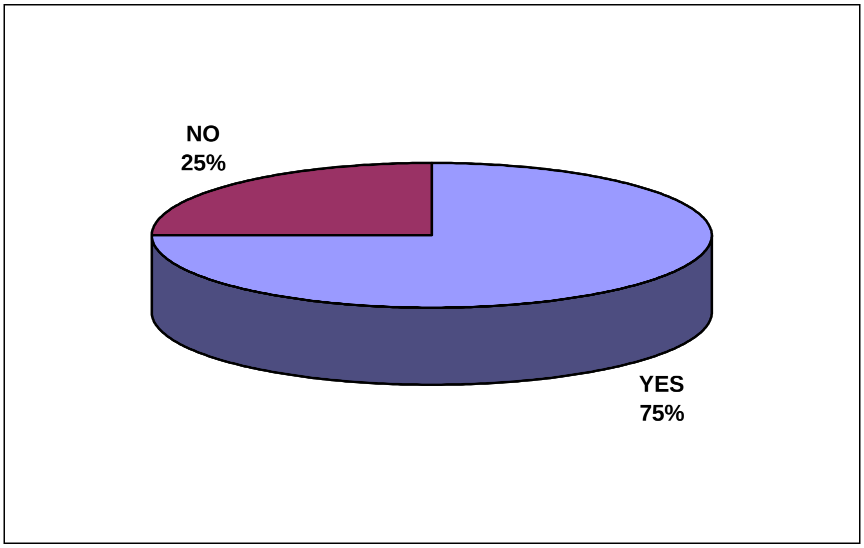


Figure 28 shows that all 12 of the surveyed respondents claim that they never skip filtration.

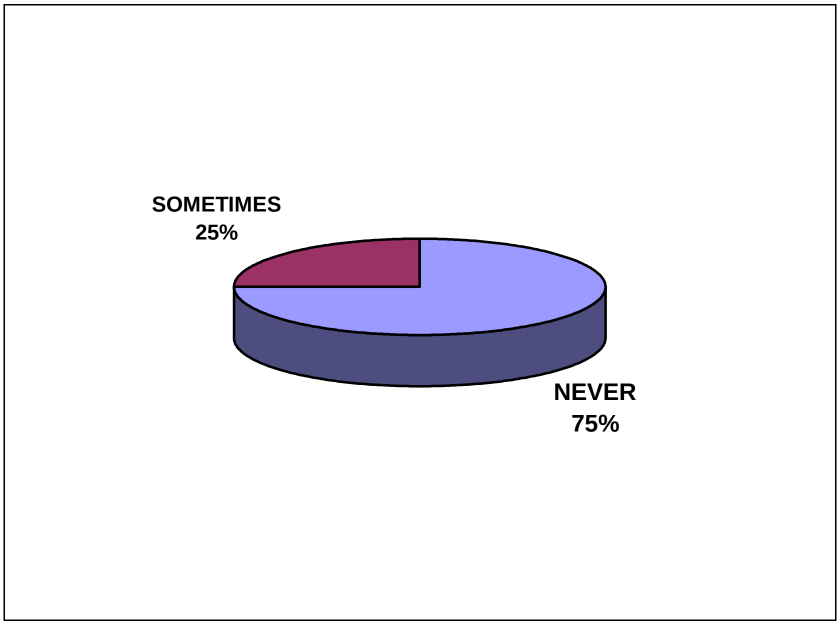
8.3.3 THREE-KOLSHI

Figure 29: Are you satisfied with the flow rate of the filter (16 respondents)?



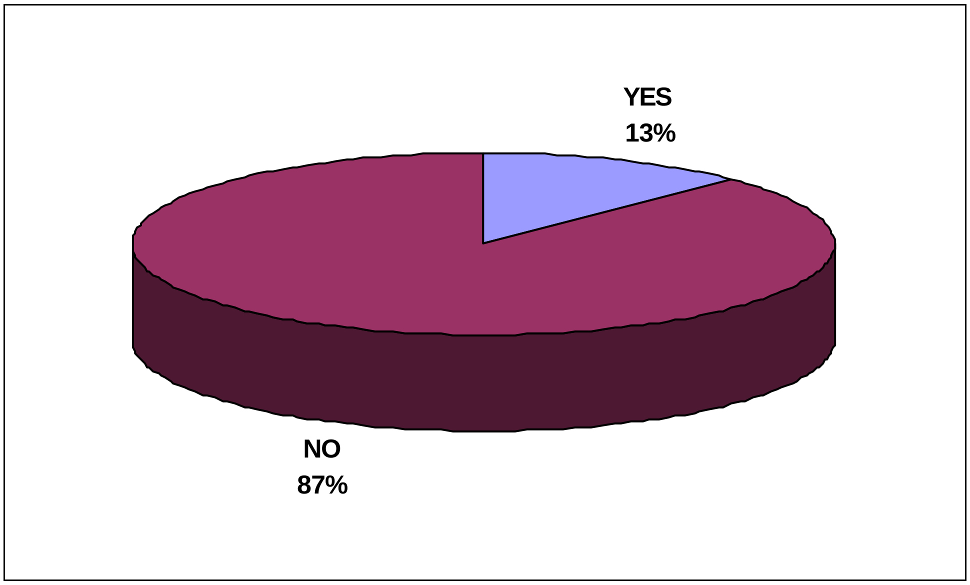
Four respondents (representing 25 % of the total surveyed) said that they were not satisfied with the flow rate of the Three-Kolshi. Furthermore, some villagers expressed their concern that the slow flow rate will not be able to cover their higher water consumption in the summer months.

Figure 30: How often do you skip filtration (16 respondents)?



Four respondents (representing 75 % of the total surveyed) said that they often skipped filtration. Half of the respondents said that they skipped filtration only when guests are present in the house and there is no time to filter enough water for all of them. By comparing the results in Figure 29 and 30 one might think that all the people who said that they were not satisfied with the flow rate also said that they sometimes skipped filtration. In fact, only 2 people asserted that they skipped filtration and were not satisfied with the flow rate. Therefore, 2 of the respondents are not satisfied with the flow rate, but nevertheless never skip filtration, while two other respondents are satisfied with the flow rate but do skip filtration sometimes. The first statistic is believable however, the second might be counter intuitive: how can someone be satisfied with the flow rate but still skip filtration? This leads us to believe that there might be another reason that pushes these respondents into skipping filtration. Unfortunately this counter-intuitive statement was not apparent to the author during the survey, and as such he could not ask the respondents in question to offer some clarification on their position.

Figure 31: Do you think that operating the filter requires too much work (16 respondents)?



Only 2 respondents (representing 13 % of the total surveyed) thought that the operating the filter requires too much work.

8.3.4 TWO-KOLSHI

Figure 32: Are you satisfied with the flow rate of the filter (19 respondents)?

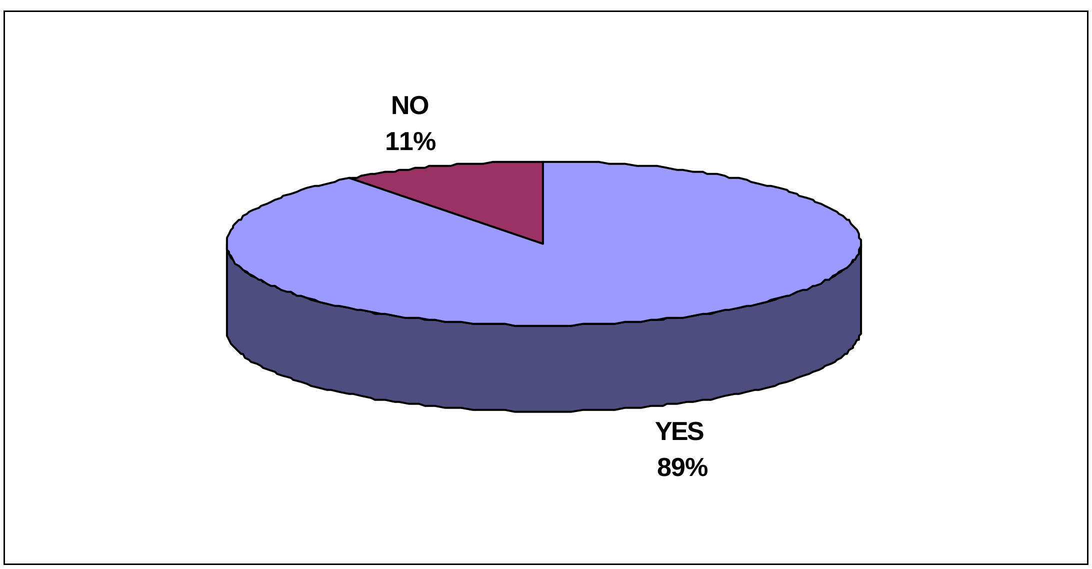
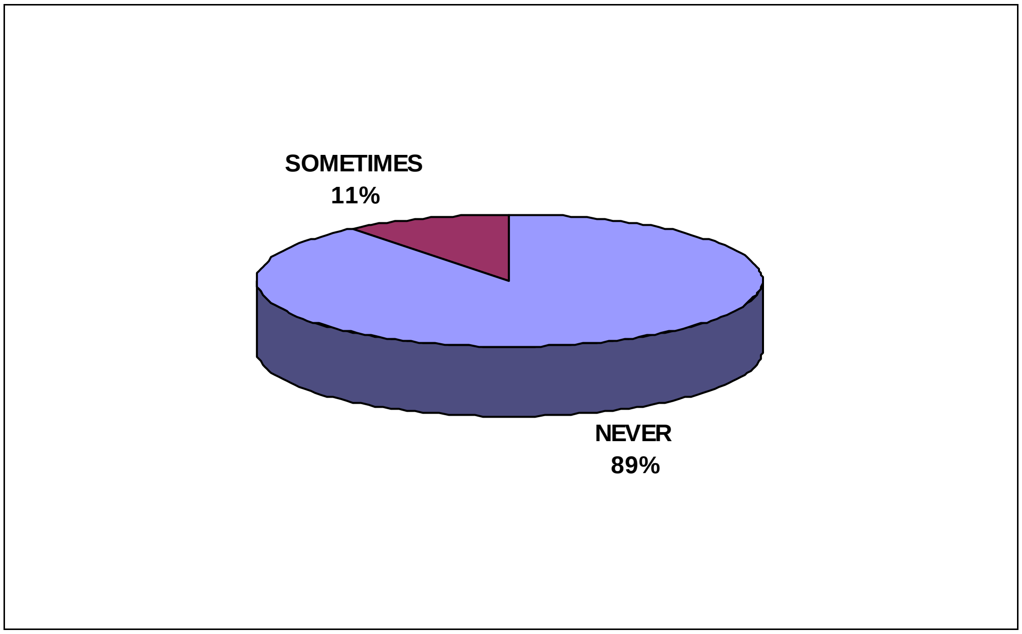
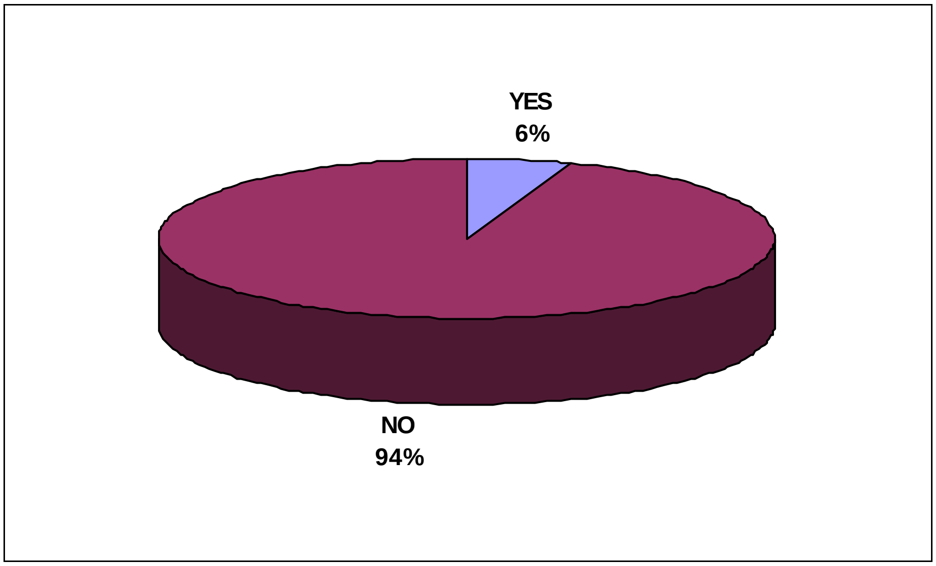


Figure 33: How often do you skip filtration (19 respondents)?



Only 2 respondents (representing 11 % of the total surveyed) said that they sometimes skipped filtration. They both said that they often returned from the fields thirsty. As such, they sometimes weren't patient enough to go through the lengthy coagulation-filtration process of the Two-Kolshi.

Figure 34: Do you think that operating the filter requires too much work (18 respondents)?



Only one person (representing 6 % of the total surveyed) said that operating the filter requires too much work.

8.3.5 IMPRESSIONS

During the course of the site visit, various incidents took place, which prompted the author to speculate about the level of arsenic and filter awareness of the surveyed population. Some of these ideas are described in this section. They should not be taken as definite truths. At best they could be a starting point for any future surveyor wanting to investigate their veracity through a formal survey, at worst they could be taken as anecdotes for anyone conducting a similar study in rural Nepal.

WILLINGNESS-TO-PAY

Because the original survey only had a willingness-to-pay question for the respondents who do not own a filter, most of the surveyed respondents were not asked about their willingness-to-pay. Furthermore, most of the answers of the people who were asked about it were judged unrepresentative by the author. This is especially true for women respondents who tend to give huge numbers for their willingness-to-pay. It is traditionally the role of men in Nepal to take care of the money matters of the household. As such, the women usually have very little understanding of these matters. The author did not prepare himself adequately for this exercise and as such could not produce a good willingness-to-pay study.

During the last few days of the trip, Upendra Paudel, the ENPHO arsenic technician assigned to the district of Nawalparasi, accompanied the author on his visits. According to him, the willingness-to-pay of the respondents should be around 1000 Nepali rupees (13 American dollars). The author shared this number with Kalawati Pokharel, the senior arsenic technician at RWSSSP, who found it reasonable. The author concluded that an approximate willingness-to-pay of the average Nepali should be around 1000 Nepali rupees.

IRON-ARSENIC CONFUSION

A good portion of the groundwater in Nepal has high iron content in addition to its high arsenic content. The filters have a very good removal rate for both metals. Unlike arsenic, iron can be tasted and seen in the water when it is present in sufficiently high concentrations. A lot of villagers stated that before the introduction of the filter into their household, their water would taste bad and look bad, their teeth would turn red and their rice would turn black when cooked. After they started using the filters, all these negative effects disappeared. A lot of the villagers considered this as proof of the unhealthiness of their well water. When these symptoms disappeared, then, surely, their water was healthier to drink. Most villagers associated the disappearance of these showings with the arsenic removal capability of the filter. There is a great deal of confusion between arsenic and iron, most people not knowing about the existence of the former, and therefore associating all the described showings with the latter. One woman actually defined arsenic as literally meaning: “high iron content”. This confusion is somewhat understandable as arsenic is invisible, odorless and tasteless.

IRON REMOVAL

As discussed earlier, some villagers associated the disappearance of effects such as bad taste, reddening of the teeth and blackness of rice with the arsenic removal capability of the filters. A lot of the villagers considered these effects as proof of the unhealthiness of their well water. When these symptoms disappeared, then, surely, their water is now healthier to drink. Other villagers didn't think that the disappearance of these showings were correlated to any health improvement, but welcomed them nevertheless because of their aesthetic improvements to their water. As such some villagers are not using the filters for their arsenic removal capabilities but for their iron removal capabilities.

LANGUAGE BARRIER

It should be noted that there is less arsenic awareness in non-Nepali villages. A lot of the "false" answers to the question on Arsenic definition came from Tharu and Madhessi villages. In the VDC of Dubiya in Kapilvastu, four people belonging to the Tharu ethnic group were asked to define Arsenic. Three of them did not know what Arsenic was, although one of them had a RWSSSP arsenic awareness poster on one of the walls of his house. Similar results were found in Madhessi households in Sarawal where the main language is Avdhi. Since most of the Arsenic technicians working for RWSSSP, Nepal Red Cross and ENPHO are Nepali, the reason behind these poor results might lie in a language barrier between some villagers and the arsenic technicians who visit them.

DISTANCE ISSUES

Another reason, which might explain the poor results in Kapilvastu, is the difficulty of accessing it from the main RWSSSP office in Butwal. The village of Rangai in the VDC of Dubiya is about two and a half hours away from Butwal. About an hour and a half of this travel time is done on jungle trails located north of the Siddharta highway. Some of these trails are only usable by four-wheel drive trucks, or at the other extreme, donkeys and horses. As such, technicians rarely visit these remote villages in Kapilvastu. The inhabitants of this district are therefore not exposed to a great deal of arsenic education, which could explain their low level of awareness.

AGE

The level of awareness seems also to be correlated with the age of the respondents. Younger respondents seem to have a higher level of Arsenic awareness then their elder counterparts in the same household. This could be explained by the fact that young people are more likely to have received a high school education than their parents. As such, concepts such as “poison”, “diseases” or “chemical elements” are more likely to mean something to them. A woman in Sunwal showed a very low level of awareness yet affirmed that she never skipped filtration. When asked why, she said that her teenage children had convinced her to do so. Although this finding is encouraging, it should be taken at its face value: only a small portion of kids in rural Nepal goes to school.

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 LIMITATIONS OF STUDY

9.1.1 CRITIQUE OF RESULTS

Many of the filter social acceptability results described above seemed to be counter-intuitive. This conclusion becomes reinforced when comparing the results of all three filters. The following section of this chapter (Potential Reasons) might help elucidate the reason behind these results.

Table 10: Comparison of the results of the three filters

QUESTION	ARSENIC-BIOSAND	THREE-KOLSHI	TWO-KOLSHI
Are you satisfied with the flow rate?	75 % (YES)	75 % (YES)	89 % (YES)
Do you think the filter requires too much work?	8 % (YES)	13 % (YES)	6 % (YES)
How often do you skip filtration?	0 % (SOMETIMES)	25 % (SOMETIMES)	11 % (SOMETIMES)

<u>Are you satisfied with the flow rate of the filter?</u>
Seventy-five percent of the respondents are satisfied with the flow rate of the Arsenic-Biosand filter. This proportion seems to be quite low considering that the Biosand filter has a flow rate sufficient to accommodate a normal size Nepali family (10-20 L/hr). This is especially striking when one compares it with the similar acceptance rate of the Tree-Kolshi (75 %), which has a much lower flow rate (0.5-3 L/hr).

<u>Do you think the filter requires too much work?</u>

As shown in the above table, 6 % of the Two-Kolshi users said that it required too much work. This low statistic is surprising as the Two-Kolshi filter is the one that requires the most work of the three filters. It can be seen in the same table that 8 % of the surveyed Biosand users said that it required too much work and as much as 11 % of the surveyed Three-Kolshi users gave the same answer even though these two filters are both much easier to use. This comparison with the results of the two other filters makes that low statistic of 6 % even more puzzling.

<u>How often do you skip filtration?</u>
As shown in the above table, 25% of the surveyed Three-Kolshi users and 11 % of the surveyed Arsenic-Biosand users said they sometimes skipped filtration. These high statistics are believable as the Three-Kolshi has a very slow flow rate and the operation of the Two-Kolshi involves a time-consuming coagulation process followed by a filtration process.
It can also be seen in this table that none of the surveyed Arsenic-Biosand users claimed that they ever skip filtration. The high flow rate of this particular filter allows the villagers to always have enough clean water, and therefore might reduce their incentive to skip filtration.

9.1.2 POTENTIAL REASONS

The following reasons may be offered to explain the counter-intuitive survey results:

- Most of the villagers that use a certain type of filter are not aware of the existence of other types of filters. They are not aware of any alternative filter that might be more acceptable to them. As such, they might view some of the hardships associated with operating their filter as an inescapable price to pay in order to have access to clean water. This could certainly explain why only 11 % of the surveyed respondents complained about the amount of work associated with operating the Two-Kolshi filter.

- One should always keep in mind that the exact same technicians who distributed the filters for free conducted this survey. As such the villagers might have felt sometimes compelled to give the answers that they think the arsenic technicians expect. This could help explain why none of the surveyed respondents admitted to ever skipping filtration of the Arsenic-Biosand filter.
- It should be remembered that the sample size is very small when it comes to each individual filter (17 samples for the Arsenic-Biosand, 18 samples for the Three-Kolshi and 19 samples for the Two-Kolshi). This size is obviously not big enough to produce convincing results on the social acceptability of each individual filter. This certainly could help explain why the survey produced counter-intuitive results.

9.2 CONCLUSIONS

9.2.1 WATER COLLECTION PRACTICES

As shown in Figure 17 of the previous chapter, 79 % of the respondents said that the women (all women or just the daughters-in-law) collect the water. As explained in the previous section, the assertion of some males that they collect the water should probably not be believed. As such, the actual share of the women in the water collection is probably higher than 79 %. This finding certainly concurs with the innumerable previous studies that established that rural women collect the water for their households.

The average distance to the main source of drinking water for the 47 villagers surveyed was found to be 5.4 m. The standard deviation was 7.5 m, which means that about two thirds of the respondents had their main water supply between 0 m and 13 m from their household. As such the travel time and work required to haul water from the wells to the houses is negligible in the visited villages. It can be inferred that the burden of collecting water in the Terai is much less pronounced than in other Nepali areas such as the central hills where the women have to sometimes walk for hours to collect water from a river, a well or even a pond. Quality of the drinking water and not quantity, is the substantial problem for the visited villages

9.2.2 ARSENIC AWARENESS

ARSENIC AS A HEALTH HAZARD

As shown in Figure 19 of the last chapter, 63 % of the respondents associated arsenic with a health hazard. These respondents defined arsenic as being a “poison”, a “disease” or a “danger”. This statistic is confirmed by the results shown in Figure 21. Sixty-six percent of the respondents said that they saw a correlation between removing arsenic from water and protecting one’s health. It is therefore safe to assert that about two thirds of the surveyed respondents consider arsenic to be a health hazard. This encouraging statistic would not be meaningful if the surveyed respondents were not aware of an arsenic contamination in their water supply. Figure 20 shows that 80 % of the respondents are aware of an arsenic contamination of their water supply. As explained on page 77 of this report, this finding does not concord with the results shown in Figure 18 where 27 % of the respondents claimed not to know what arsenic was. It is therefore safe to assert that the percentage of the respondents that actually are aware of arsenic contamination of their wells falls between 70 and 80.

Since arsenic was discovered in Nepal recently, these results seem to indicate a relatively high level of arsenic awareness in Nepal. It should be remembered that the first discovery of an arsenic contaminated well in Nepal was in 1999. The filters were first distributed to the affected villagers in 2002, or about three years later. This study was conducted in January 2003, 4 years after the first arsenic discovery and only a few months after the initiation of the filter distribution. In light of these considerations, the statistics revealed by this portion of the survey are extremely encouraging, and demonstrate a relative high level of arsenic awareness that will presumably only increase in the coming years, or even months. This assertion is only confirmed by comparing Nepal’s response to its arsenic problem with the response of other affected areas such as Bangladesh and West Bengal.

Arsenic was first discovered in Bangladesh in 1981 and in West Bengal in 1984. Yet, it was not until the mid-1990's that the problem emerged into broad public awareness and effective responses to the problem were implemented. In other words, it took more than a decade for these countries to achieve the level of awareness that was achieved in Nepal in less than four years. Since the author is not familiar with the intricacies of the arsenic problem in these other places, he will not try to compare the response of these countries to this problem with the response of Nepal. Nevertheless he will try to indicate below what he believes are the reasons behind the relative speed of response in Nepal.

The relative high level of awareness shown in this study can only be attributed to the remarkable work of some NGO's in Nepal. Although the Nepalese Department of Water Supply and Sewerage and its main funder UNICEF-Nepal were instrumental in the initial testing of wells for arsenic in 1999, they have relegated themselves to a lesser role in the response stage that followed. It is the various NGO's on the ground that actually researched the various response mechanisms at their disposal and distributed the household filters currently in use. These organizations are: RWSSSP, Nepalese Red Cross and its main funder the Japanese Red Cross and ENPHO which is, in effect, a sub-consultant of the Nepal Red Cross. They resorted to various mechanisms to increase the level of awareness of the population, some of which are as described below:

- Many arsenic awareness meetings were conducted in the affected villages. These meetings usually consist of a talk given by arsenic technicians followed by a question and answer period. The talk component is always accompanied by visual aids such as posters, pictures or when electricity is available, a video.
- After the filters are initially distributed, the arsenic technicians continuously monitor their use. They often visit the villages to test the treated water from the filters and in the process engage the villagers in discussions about the arsenic problem and the filters in use.

- The various NGO's have studied the arsenic problem in neighboring Bangladesh extensively, and have applied many of the lessons learned over there. Some high level employees have even visited Bangladesh several times to get a hands-on approach to its arsenic problem.

It should also be noted that the government has had some role in this education campaign. A big proportion of the villagers with access to television have watched a documentary on arsenic that ran on the state-run Nepalese television channel. In fact, many of these villagers said that they first heard of arsenic from this particular documentary.

9.2.3 FILTER AWARENESS

As stated earlier, the female members of the household mainly do the water collection. However, the same does not hold for the filter cleaning. As showed in Figure 22 the filter cleaning is more distributed among various family members. Sixty-three percent of the respondents affirm that the filter cleaning is done exclusively by women (wives, daughters-in-law or all women). It should be noted that 15 % of the respondents said that all family members undertake this task. This would mean that the women's share of the task is actually higher than 63 %. As such women still represent about 64 % of the total, but men have a greater share in the cleaning than in the water collection. This result concurs with previous findings that found that men tend to be more involved in the technical chores of water issues, such as repairing broken tube wells for example.

9.2.4 SOCIAL ACCEPTABILITY OF EACH TYPE OF FILTER

As described in section 9.1.1, the survey results related to the social acceptability results of each type of filter appeared counter-intuitive. Potential reasons that might explain why the survey produced these counter-intuitive results were enumerated in section 9.1.2. Because of these counter-intuitive results, no conclusions on the social acceptability of the filters will be included in this report.

9.3 RECOMMENDATIONS

9.3.1 GUIDELINES FOR FUTURE STUDIES

It is the intent of the author in this section to give recommendations for future social acceptability studies. Some of these recommendations may seem very obvious to experienced surveyors but they were not to the author prior to him going to Nepal.

- A large sample population is necessary to produce representative results. A surveyor might not feel confident in being able to survey a large number of people due to time constraints or others. If this is the case, then he should consider reducing the scope of his study or even canceling it altogether.
- Ideally, the surveyor would speak the native tongue of the people surveyed. Lacking that, it is imperative to have excellent translators accompanying the surveyor. A good social acceptability survey requires a lot of open-ended questions. It is sometimes necessary for the surveyor to read in between the lines of people's answers. As such an excellent translation is required to catch all the subtleties of the answers.
- The surveyor should always have a local counterpart that will take part in all the aspects of the survey, from creating a questionnaire to conducting the survey and writing the final report. A local "associate" will be able to provide insight into many questions that the surveyor cannot be able to address due to his foreign status.
- The survey instrument should not include questions that require the respondents to give a timeframe around their actions. When respondents were asked in this study how often they skipped filtration, they were not able to answer in terms of units of time. They were only able to give two answers: "never" and "sometimes". It is the author's conclusion that all of the surveyed respondents do not have a concept of time similar that is similar to the Western one.

- It is imperative that the people accompanying the surveyor be chosen so they do not influence the answers of the respondents. As stated previously, the technicians who accompanied the surveyor in this study were the ones who distributed the filters for free to the villagers a few months earlier. As such some villagers knew exactly what were the answers that the technicians expected on the arsenic awareness and filter social acceptability questions of the survey instrument.
- Any future study should have a much smaller scope than the one attempted by the author. It is the author's belief that the scope of his study was too large and his time in Nepal too small for him to produce convincing answers on the questions he attempted to answer.

9.3.2 RECOMMENDATIONS FOR FUTURE PROJECTS

Throughout this study, whether it was in Nepal or in Cambridge, numerous future arsenic-related potential projects presented themselves to the author. It is the intent of the author in this section to present some of them.

<u>IMPROVEMENT OF THE THREE-KOLSHI</u>

Upendra Paudel, the ENPHO arsenic technician for the district of Nawalparasi, proposed this idea. It is his belief that if it weren't for its much slower flow rate then the other two filters (0.5-3 L/hr), the Three-Kolshi would be the best alternative of all three filters. The capital cost of the Three-Kolshi (500 Nepali rupees) is much lower than the other two filters and it doesn't involve any operation and maintenance costs. This cost fit within Mr. Paudel's estimated willingness-to-pay range of the population, which is around 1000 Nepali rupees. The filter is also made of readily available materials, which can allow villagers to eventually build their own filters. Mr. Paudel's suggestion for future project, and the author concurs with it, is to modify the Three-Kolshi filter so as to increase its flow rate.

<u>CONCENTRATED STUDY ON ARSENIC AWARENESS</u>

In section 9.2.2 the author described some of his conclusions on the level of arsenic awareness of the surveyed population. He also speculated on this topic in section 8.3.5. The author recommends a concentrated study on arsenic awareness that would try to prove or disprove these observations. A questionnaire-based survey with a multi-variate type of data analysis should be considered for this study. This type of survey would allow the surveyor to examine the impact of various population characteristics (household income, ethnic group etc…) on the level of arsenic awareness of the surveyed population.

WILLINGNESS-TO-PAY STUDY OF AN ARSENIC FILTER

A complete and thorough willingness-to-pay study of the population would be especially useful in determining the social acceptability of the three filters. This study should include an extensive background research on some of the contingency valuation papers written in the past.

CONCENTRATED SOCIAL ACCEPTABILITY STUDY ON ONE TYPE OF FILTER

As stated previously, this study suffered from the broadness of its scope. As such it is recommended that a future similar study address only the social acceptability of one type of filter. It is the author's belief that priority should be given to the Arsenic-Biosand filter as it has come to his attention in the last months, through its designer Tommy Ngai, that RWSSSP is considering distributing it on a wide scale. Upendra Paudel also told the author that ENPHO is also considering distributing the filter on a wide scale. Furthermore, ENPHO is currently working on the design of a fiberglass and plastic version of the Arsenic-Biosand that would cost 1700 Nepali rupees (30 American dollars). This potential new filter would be a cheaper alternative to the current Arsenic-Biosand filter, made out of concrete and costing about 2000 Nepali rupees (36 American dollars). Any future study on the Arsenic-Biosand filter could examine the question of which version would be the most socially acceptable.

If this potential future project is conducted in the context of the MIT M.Eng program, a questionnaire-based survey with a multi-variate type of analysis should be used. If it were conducted with more time and personnel then typically used in an M.Eng product, an RA type of survey should be used.

APPENDIX I: ORIGINAL SURVEY-SURVEY 1

BACKGROUND

Caste: ____________________________

Ethnicity: _________________________

Gender: __________________________

Age: _____________________________

How many people live in your household?
____

WATER QUALITY

1. How would you rate the quality of the water that you use?

____ Good ____ Average
____ Poor ____ Don't know

2. Do you know what Arsenic is?

____ Yes ____ No

3. Are you aware of any Arsenic contamination in your water?

____ Yes ____ No

4. Have you ever exhibited symptoms of arsenic poisoning (this question will be accompanied by a description of what these symptoms are)?

____ Yes ____ No

5. Has anyone in your family ever exhibited these symptoms?

____ Yes ____ No

6. Have you ever met anyone who exhibited these symptoms?

____ Yes ____ No

7. Do you see a correlation between removing the arsenic from your water and protecting your health?

____ Yes ____ No
____ Not sure

8. What is your household's main source of drinking water?

___ Private connection _________Inside home_________ Outside home
___ Shared connection
___ Private well with pump
___ Private well hand drawn
___ Public tap
___ Public tubewell with handpump
___ Vendor / Purchase from private person
___ Surface water (describe: river, spring, etc __________________)
___ Captage
___ Other (describe) ________________________________

9. What other source do you occasionally use?
___ Private connection _________Inside home_________ Outside home
___ Shared connection
___ Private well with pump
___ Private well hand drawn
___ Public tap
___ Public tubewell with handpump
___ Vendor / Purchase from private person
___ Surface water (describe: river, spring, etc __________________)
___ Captage
___ Other (describe) ________________________________
___ None

10. How far from your home is your primary water source?
_______________ meters
_____________ minutes walking time (one way)

11. Who, in your household, is in charge of collecting the water?

____

12. How much water does your household use on a daily basis?
(if subject doesn't know, then ask questions that might give us clue on quantity)

____
____

FILTERS

1. What type of arsenic removal filter are you currently using?
____ None ____ ENPHO filter
____ Three Kolshi filter ____ Arsenic-Biosand filter
____ Other ____

2. Who, in your household, is in charge of filtering the water?

____

For **none**:

3. Have you ever heard of an arsenic removal filter?

_____ Yes _____ No

4. Do you think that installing an arsenic removal filter will protect your health and your family's?

_____ Yes _____ No

_____ Don't know

5. Why haven't you installed an arsenic removal filter yet?

____

6. How much capital cost would you be ready to pay for a filter?

____

7. How much operation and maintenance cost would you be ready to invest every year?

____

8. How much work would you be ready to put in on a daily basis to operate the filter?

_____ Less then 10 minutes _____ 10 – 30 minutes

_____ 30 – 60 minutes _____ 60 – 90 minutes

_____ As long as necessary

For **any filter**:

9. Why do you treat the water?

_____ To remove arsenic _____ Social custom

_____ Recommendation from NGO _____ Don't know

_____ Other ____

10. Do you feel that using the filter is actually improving the health of your household?

_____ Yes _____ No

_____ Not sure

11. Are you satisfied with the flow rate of the filter?

_____ Yes _____ No

12. How often do you skip filtration?

_____ Often (Daily) _____ Occasionally (Weekly)

_____ Rarely (Monthly) _____ Yearly

_____ Never

13. Why do you skip filtration?

_____ Filtration's too slow
_____ Too much work
_____ Don't have access to necessary equipment
_____ Too expensive
_____ Has bad taste
_____ Too complicated
_____ Don't believe it works
_____ Don't need it
_____ Other ____

14. Do you think the capital cost associated with the filter is too high?

_____ Yes
_____ No

15. Do you think the operation and maintenance costs associated with the filter are too high?

_____ Yes
_____ No

16. Do you think that operating the filter requires too much work?

_____ Yes
_____ No

17. Do you have a complaint/recommendation that you would like to share about this filter?

____
____
____
____

For **Two-Kolshi filter**

18. Are you having trouble obtaining the ferric chloride tablets?

_____ Yes
_____ No

19. If yes, what kind of problems are you encountering?

_____ Don't know where to obtain the tablets
_____ Have to travel long distances
_____ Tablets too expensive
_____ Don't trust them
_____ Other ____

20. Are you following ENPHO's directives exactly when it comes to stirring the water?

_____ Yes
_____ No

21. If no, how often do you skip them?

_____ Often (Daily)
_____ Rarely (Monthly)
_____ Occasionally (Weekly)
_____ Yearly

For **Arsenic-Biosand filter and Three-Kolshi**

22. When do you clean the filter?

____ When it clogs completely ____ When it clogs half way

____ On a __________ basis ____ Never

____ Other ____

APPENDIX II: REVISED SURVEY- SURVEY 2

BACKGROUND

Gender: __________________________

Age: _____________________________

How many people live in your household?
____

WATER QUALITY

1. How would you rate the quality of the water that you use?

____ Good ____ Average
____ Poor ____ Don't know

2. Do you know what Arsenic is?

____ Yes ____ No

3. If yes, what is it?

____

4. Are you aware of any Arsenic contamination in your water?

____ Yes ____ No

5. Do you see a correlation between removing the arsenic from your water and protecting your health?

____ Yes ____ No
____ Not sure

6. What is your household's main source of drinking water?

___ Private connection _________Inside home_________ Outside home
___ Shared connection
___ Private well with pump
___ Private well hand drawn
___ Public tap
___ Public tubewell with handpump
___ Vendor / Purchase from private person
___ Surface water (describe: river, spring, etc ___________________)
___ Captage
___ Other (describe) __________________________________

7. What other source do you occasionally use?

___ Private connection __________Inside home__________ Outside home
___ Shared connection
___ Private well with pump
___ Private well hand drawn
___ Public tap
___ Public tubewell with handpump
___ Vendor / Purchase from private person
___ Surface water (describe: river, spring, etc ___________________)
___ Captage
___ Other (describe) ___________________________________
___ None

8. How far from your home is your primary water source?
________________ meters
______________ minutes walking time (one way)

9. Who, in your household, is in charge of collecting the water?
____

10. How much water does your household use on a daily basis?
(if subject doesn't know, then ask questions that might give us clue on quantity)
____
____

FILTERS

1. What type of arsenic removal filter are you currently using?
____ None
____ Three Kolshi filter
____ Other ____
____ ENPHO filter
____ Arsenic-Biosand filter

2. Who, in your household, is in charge of filtering the water?
____

3. How much capital cost would you be ready to pay for a filter?
____

4. How much operation and maintenance cost would you be ready to invest every year?
____

For **none**:

5. Have you ever heard of an arsenic removal filter?

_____ Yes _____ No

6. Do you think that installing an arsenic removal filter will protect your health and your family's?

_____ Yes _____ No
_____ Don't know

7. Why haven't you installed an arsenic removal filter yet?

____

8. How much work would you be ready to put in on a daily basis to operate the filter?

_____ Less then 10 minutes _____ 10 – 30 minutes
_____ 30 – 60 minutes _____ 60 – 90 minutes
_____ As long as necessary

For **any filter**:

9. Why do you treat the water?

_____ To remove arsenic _____ Social custom
_____ Recommendation from NGO _____ Don't know
_____ Other ____

10. Do you feel that using the filter is actually improving the health of your household?

_____ Yes _____ No
_____ Not sure

11. Are you satisfied with the flow rate of the filter?

_____ Yes _____ No

12. How often do you skip filtration?

_____ Often (Daily) _____ Occasionally (Weekly)
_____ Rarely (Monthly) _____ Yearly
_____ Never

13. Why do you skip filtration?

_____ Filtration's too slow _____ Has bad taste
_____ Too much work _____ Too complicated
_____ Don't have access to necessary equipment _____ Don't believe it works
_____ Too expensive _____ Don't need it
_____ Other ____

14. Do you think the capital cost associated with the filter is too high?

_____ Yes _____ No

15. Do you think the operation and maintenance costs associated with the filter are too high?

____ Yes ____ No

16. Do you think that operating the filter requires too much work?

____ Yes ____ No

17. Do you have a complaint/recommendation that you would like to share about this filter?

____
____
____
____

For **Two-Kolshi filter**

18. Are you having trouble obtaining the ferric chloride tablets?

____ Yes ____ No

19. If yes, what kind of problems are you encountering?

____ Don't know where to obtain the tablets ____ Tablets too expensive
____ Have to travel long distances ____ Don't trust them
____ Other ____

20. Are you following ENPHO's directives exactly when it comes to stirring the water?

____ Yes ____ No

21. If no, how often do you skip them?

____ Often (Daily) ____ Occasionally (Weekly)
____ Rarely (Monthly) ____ Yearly

For **Arsenic-Biosand filter and Three-Kolshi**

22. When do you clean the filter?

____ When it clogs completely ____ When it clogs half way
____ On a __________ basis ____ Never
____ Other ____

APPENDIX III: JOURNAL OF DAILY SITE VISITS

The January field visits to the various arsenic sites in the Terai started on January 4, 2003 and ended on January 17, 2003. A concise journal of these sites visits is offered below.

January 4: Arrival to Butwal.
January 5: Visit to the VDC of Sarawal in the district of Nawalparasi.
Five well samples and five Arsenic-Biosand filter samples were taken. As far as anyone knows this is the VDC that has the highest number of cases of arsenicosis. One individual exhibiting signs of keratosis came to me and showed me his hands.
January 6: Visit to the VDC of Devdaha in the district of Rupendehi.
Two well samples and three Arsenic-Biosand filter samples were taken. Five people were also surveyed.
January 7: Visit to the VDC of Barkalpur in the district of Kapilvastu.
One well sample and three 3-Kolshi filter samples were taken. Six people were surveyed. The visited village, Dhamauli, seems to be one of the poorest ones visited during the trip.
January 8: Visit to the VDC of Sunwal in the district of Nawalparasi.
Four households using two-kolshi filters were surveyed. The households visited all had access to electricity and a couple of them owned televisions.
January 9: National Holiday in Nepal. No fieldwork was undertaken.
January 10: Visit to the VDC of Sunwal in the district of Nawalparasi.
Two well samples and two two-kolshi filter samples were taken. Seven households were surveyed.
January 11: No fieldwork was undertaken, as RWSSSP doesn't operate on Saturdays.
January 12: Visit to the VDC of Sarawal in the district of Nawalparasi.
One well and one Arsenic-Biosand filter were sampled. In addition, three households were surveyed. One of the visited households had a member who exhibited signs of keratosis and two members who exhibited signs of melanosis.
January 13: Visit to the VDC of Dubiya in the district of Kapilvastu.
Four households owning Three-Kolshi filters were surveyed. The village visited, Rangai, is two hours and a half away from Butwal. An hour and a half of the trip is done on

jungle trails accessible only by four by four truck, or at the other extreme, donkeys and horses. The village appeared to be the poorest one visited during the trip. The main language of the village was Tharu, as such there was a bit of a communication problem between the surveyed villagers and my translators who only spoke Nepali.

January 14: Visit to the VDC of Panchangar in the district of Nawalparasi.

Eight households owning Three-Kolshi filters were surveyed. An ENPHO arsenic technician by the name of Upendra guided the visit, as Panchangar is not under the jurisdiction of RWSSSP.

January 15: Visit to the VDC of Panchangar in the district of Nawalparasi under the guidance of Upendra.

Three wells and three Arsenic-Biosand filters were samples. Five households were surveyed. One of the households visited had a member exhibiting signs of keratosis.

January 16: Visit to the VDC of Sarawal in the district of Nawalparasi.

Three wells and three Arsenic-Biosand filters were sampled. Four households were surveyed. Three of the visited households had members who exhibited signs of keratosis or melanosis.

January 17: Visit to the VDC of Panchangar in the district of Nawalparasi Nawalparasi under the guidance of Upendra.

Eight households owning Two-Kolshi filters were visited. Two of the visited households had members who exhibited signs of keratosis or melanosis.

REFERENCES

Adeel. Academic Programme Officer Environment and Sustainable Development, United Nations University. "Arsenic Crisis Today – Strategy for Tomorrow". Rev. 2001. Internet.
Available: <http://www.unu.edu/env/water/arsenic/policy-brief.html> (May 9, 2003).

Bista, Dor Bahadur. Fatalism and Development: Nepal's Struggle for Modernization. Hyderabad, India: Orient Longman Limited. 1991.

Bridge, T. "Arsenic Crisis: A Challenge for Scientists to find the origin of the Arsenic that caused the Poisoning Disaster in Bangladesh". University of Kansas, Kansas, USA. 2000.

British Geological Survey. "Groundwater studies for Arsenic Contamination in Bangladesh". Main Report and Supplemental Volumes 1-3, Government of the People's Republic of Bangladesh, Ministry of Local Governments, Rural Development and Cooperatives, Department of Public Health Engineering, Dhaka, Bangladesh. 1999. Internet.
Available: <http://www.bgs.ac.uk/arsenic/bphase1/b_intro.htm> (May 15, 2003).

Clasen, T. "Evaluation of Ceramic Microfilter in Bolivia". Unpublished research plan. London School of Hygiene and Tropical Health. London. 2003.

Cullen, W.R. and K.J. Reimer. "Arsenic speciation in the environment". *Chem. Rev.*, No. 89, Pages 713-764. 1999.

Crisis information center. "West Bengal and Bangladesh arsenic". Rev. 2003. Internet.
Available: <http://bicn.com/acic/> (May 9, 2003).

Environmental and Public Health Organization. "Drinking Water Quality Improvement Program, Annual Report". September 2001.

Environmental Protection Agency (EPA). "Arsenic in Drinking Water, Fact Sheet". Rev. 2003. Internet.
Available: http://www.epa.gov/safewater/arsenic.html (May 9, 2003).

Environmental Protection Agency (EPA). "Environmental Technology Verification Report, Quick Arsenic Test Kit". 2002.

Fazal, Toshihiko Kawachi and Eiji Ichion. "Extent and Severity of Groundwater Arsenic Contamination in Bangladesh". *Water International*, Volume 26, Number 3, Pages 370-379. September 2001. Internet.
Available: http://www.eng-consult.com/arsenic/article/Fazal20014R.pdf (May 9, 2003).

Harun-ur-Rashid and Md. Abdul Karim Mridha. "Arsenic Contamination of Groundwater in Bangladesh". 24th WEDC Conference, Water and Sanitation for All. Islamabad, Pakistan. 1998. Internet.
Available: <www.lboro.ac.uk/departments/cv/wedc/papers/24/E/rashid.pdf> (May 9, 2003)

Hwang, S. "Point-of-Use Arsenic Removal from Drinking Water in Nepal Using Coagulation and Filtration". Master of Engineering Thesis. Massachusetts Institute of Technology. Cambridge, Massachusetts. June 2002.

Mahmood, S. "The silent killer is engulfing Bangladesh". *The Independent*. July 3, 2002. Interntet.
Available:<http://www.bcas.net/Env.Features/HumanHealth/July2002/1%20to%2015.html> (May 9, 2000).

Manderson and Aaby. "An epidemic in the field? Rapid Assessment procedures and health research" Soc. Sci. Med., Vol. 35, No.7, Pages 839-850. 1992.

Meyer, K. and Deuel, P. "The Tharu of the Tarai". Rev. 2003. Internet.
Available: <http://www.asianart.com/tharu/> (May 9, 2003).

Murcott, S. and Lucaks, H. "Household Water Treatment in Nepal". Unpublished paper. Cambridge, Massachusetts. 2002.

Murcott, S. "3-Kalshi System". Rev. October 2000. Internet.
Available: <http://mit.edu/murcott/www/arsenic/templates/A7Kalshi.htm> (May 9, 2000).

National Academy of Sciences (NAS). Arsenic: Medical and biological effects of environmental pollutants". Washington, D.C., USA: National Academy Press. 1977.

Nepal Red Cross Society. "Research on Arsenic Contamination in the Groundwater of Terai Nepal". September 2000.

Nepal's People and Ethnic Groups. "Nepal's Cultural Groups per altitude". Rev. 2003. Internet.
Available: <http://www.visitnepal.com/nepal_information/people.htm> (May 9, 2003)

Ngai, T. "Arsenic speciation and evaluation of an adsorption media in Rupandehi and Nawalparasi districts of Nepal". Master of Engineering Thesis. Massachusetts Institute of Technology. Cambridge, Massachusetts. June 2002.

Ngai, T. and Walewijk, S. "The Arsenic-Biosand Filter (ABF) project". Unpublished research paper. Cambridge, Massachusetts. 2003.

Nimick, D.A., J.N. Moore, C.E. Dalby, and M.W. Savka. 1998. "The fate of geothermal arsenic in the Madison and Missouri Rivers, Montana and Wyoming". *Wat. Res. Research,* Vol 34, Pages 3051-3067. 1998.

NMIDP. "National Minor Irrigation Development Project, National Minor Irrigation Census 1996/1997". Sir William Halcrow and Partners Ltd and DHV Consultants BV, Dhaka, Bangladesh. Pages 1-19. 1998.

Paynter, T. "Household Water Use and Treatment Practices in Rural Nepal, Biosand Filter Evaluation and Considerations for Future Projects". Master of Engineering Thesis. Massachusetts Institute of Technology. Cambridge, Massachusetts. June 2002

Reed, D. The Rough Guide to Nepal. United Kingdom: Rough Guides. September 1992.

Rhodes, Stimson, Fitch, Ball and Renton. "Rapid Assessment, injecting drug use, and public health". *The Lancet*. Vol. 354. July 1999.

Sullivan, H. "Household Water Chlorination for the Developing World, A case Study in Lumbini Nepal". Master of Engineering Thesis. Massachusetts Institute of Technology. Cambridge, Massachusetts. June 2002.

Technische Universitat Bergakadenie Freiberg. "Arsenic in Groundwater Water". Rev. Nov 28, 2001. Internet.
Available: <www.geo.tu-freiberg.de/~planer/arsenic/home.htm> (May 9, 2003).

United Nation's Children Fund (UNICEF), "Nepal Statistics" Rev. April 23, 2001. Internet.
Available: <http://www.unicef.org/statis/Country_1Page123.html> (May 9, 2003).

United Nations Development Program (UNDP), "Nepal Human Development Report". Rev. 2001. Internet.
Available: <http://www.undp.org.np> (May 9, 2003).

United States Geological Survey. "Arsenic bearing minerals". Rev. Nov 28, 2001. Internet.
Available: <http://www.brr.cr.usgs.gov/arsenic/minerals.html> (May 9, 2003).

United States Environmental Protection Agency. "Locating and Estimating Air Emissions From Sources of Arsenic and Arsenic Compounds". USEPA Office of Air Quality Planning and Standards, Research Triangle Park, NC. Document No. EPA-454-R-98-013. June 1998. Internet.
Available: <http://www.icconsultants.co.uk/expascan.html> (May 9, 2003).

Uttam K. Chowdhury, Bhajan K. Biswas, Tarit Roy Chowdhury, Gautam Samanta, Badal K. Mandal, Gautam C. Basu, Chitta R. Chanda, Dilip Lodh, Khitish C. Saha, Subhas K. Mukherjee, Sibtosh Roy, Saiful Kabir, Quazi Quamruzzaman, and Dipankar Chakraborti.

"Groundwater Arsenic Contamination in Bangladesh and West Bengal, India". *Environmental Health Perspectives*, Vol. 108, No. 5. May 2000. Internet. Available: <http://ehpnet1.niehs.nih.gov/docs/2000/108p393-397chowdhury/abstract.html> (May 9, 2003).

Varghese, A. "Point-of-Use Water Treatment Systems in Rural Haiti, Human Health and Water Quality Impact Assesment". Master of Engineering Thesis. Massachusetts Institute of Technology. Cambridge, Massachusetts. June 2002.

Welch, A.H.; M. Lico, and J. Hughes. "Arsenic in ground water of the western United States". *Ground water*, Vol. 26, Pages 333-347. 1988.

World Bank. "Nepal at a Glance". Rev. April 23, 2001. Internet. Available: <http://devdata.worldbank.org> (May 9, 2003).

World Health Organization. 2000. "Towards an Assessment of the Socioeconomic Impact of Arsenic Poisoning in Bangladesh". Geneva. 2000. Internet. Available: <http://www.who.int/water_sanitation_health/Arsenic/arsenicpois.htm> (May 9, 2003).

World Health Organization. "Arsenic in Drinking Water". Rev. May 2001. Internet. Available: <http://www.who.int/inf-fs/en/fact210.html> (May 9, 2003).