Prevalence Survey of Arsenicosis in Kailali and Bardiya Districts of Nepal

FINAL REPORT

Submitted by

Mr. Shyam Prasad Adhikari
Mr. Madhu Kumar Khadaka Chhetri

Submitted to

Nepal Health Research Council
Ram Shah Path, Kathmandu, Nepal
December, 2008

ACKNOWLEDGEMENT

I would like to thank a number of individuals and organizations for bringing to completion of this research project. Appreciation is acknowledged to those individuals and organizations which provided valuable guidance, assistance and technical documents throughout the study.

I express my sincere gratitude to NHRC board and Dr. Mahesh Kumar Maskey, the then executive chairman, in particular for providing me this opportunity. I would like to gratefully acknowledge Mr. Meghnath Dhimal, Environmental health officer, for his continuous support during the study period.

I would like to appreciate the support rendered by all the administrative and financial staff of NHRC.

Sincere thanks to Dr. Sambhu D. Joshi, Medical Officer DPHO Kailali, for his valuable contribution during the study. I like to gratefully acknowledge to Mr. Manoj Chaudhary and Ganesh Chaudhary for their valuable assistance during the field study.

I owe to Mr. Krishna Prasad Upadhaya (Hydrologist, Underground Water Development Project, Banke) and Mr. Mahesh Pokhrel (Hydrologist, Underground Water Development Project, Kailali) much for their valuable support during the field study.

Finally, I would like to extend my special appreciation to communities of the study area, Department of drinking water supply and sanitation program and all the central and district level institutions associated with Arsenic activities for providing me essential assistance.

Shyam Prasad Adhikari (M. Sc.)
Principal Investigator

TABLE OF CONTENT

ABBREVIATIONS AND ACRONYMS

µg/l	:	Microgram per Liter
AASL	:	Arsenic-associated skin lesions
ATSDR	:	Agency for Toxic Substances and Disease Registry
BMI	:	Body mass index
CBS	:	Central Bureau of Statistics
CCA	:	Chromated copper arsenate
CI	:	confidence interval
DNA	:	Deoxyribonucleic acid
DWSS	:	Department of Water Supply and Sewerage
ENPHO	:	Environment and Public Health Organization
FHGAAS	:	The flow injection hydride generation atomic absorption spectrometry
gm	:	gram
JRCS	:	Japan Red Cross Society
kg	:	Kilogram
mg	:	milligram
NASC	:	National Arsenic Steering Committee
ng	:	nanogram
NRCS	:	Nepal Redcross Society
OR	:	Odd Ratio
ppb	:	Parts per Billion
R^2	:	coefficient of determination
SES	:	socioeconomic status
SPSS	:	Statistical Package for the Social Sciences
UNF	:	United Nations Foundation
USEPA	:	United State Environmental Protection Agency
UV	:	ultraviolet
VDC	:	Village Development Committee
WHO	:	World Health Organization

EXECUTIVE SUMMARY

Arsenic has been known for years to be a very poisonous element and arsenicosis is one of the burning issues in Nepal today. In lowlands of Nepal, the Arsenic concentration in the pumped "drinking" water have shown to be of such a magnitude that the population in these areas, by switching from surface water to groundwater, can be said to have come from the frying-pan into the fire. Kailali and Bardiya districts are most affected districts of western Terai where majority of residence are from Tharu community and have little or no knowledge on arsenic, its poisoning and possible mitigation measures. Unfortunately, research activities on prevalence of arsenicosis and awareness raising and mitigation activities are lacking in these areas. Hence, it was imperative to explore current status on prevalence of arsenicosis to undertake relevant actions to minimize, if possible alleviate, arsenicosis impacts. This study, therefore, was conducted to find out the prevalence of arsenicosis and its association with other socio-economic factors among the risk population in the different communities of Thapapur and Sadepani VDCs of Kailali district and Mohamadpur and Jamuni VDCs of Bardiya district. This comprehensive project adopted questionnaire survey and examination of skin laison by the experts using WHO flow chart algorithm as its major study methods. Key findings of the study illustrate that (a) the impact of arsenic problem in study area is significant with the overall prevalence of arsenicosis as 2.12% in Kailali district and 2.66% in Bardiya district; (b) Gender has apparent effect on the prevalence of arsenicosis indicating much higher symptoms among males than in females; (c) The people from older age group are affected significantly to a far greater extent than people from younger age group and a virtually negligible prevalence among those less than 15 years old; and (d) The people from poor socioeconomic group are affected significantly to a far greater extent than people from non-poor socioeconomic group. Since major causes of arsenicosis problem are poverty, illiteracy and lack of mitigating and monitoring measures, arsenic mitigation programmes should target the arsenic exposed malnourished poor population as a priority. Moreover, it is hoped that the result of this project will assist the concern authorities of Government of Nepal in formulating effective management plans for the mitigation of arsenicosis.

CHAPTER-I

INTRODUCTION

1.2 Background

Safe drinking water is still an important issue in Nepal. Until 1970s, most rural people of Terai region of Nepal obtained and consumed water from dug-wells, rivers, canals or ponds. These contaminated waters were consumed directly without any treatment. Therefore, epidemics of cholera, diarrhea, typhoid and other water-borne diseases were very common. Thousands of people particularly the infants died only because of drinking these unsafe waters. From 1980s, an idea of tapping ground water came as the most popular program for controlling many waterborne diseases by providing clean and pathogen free drinking water. Agencies and individuals installed a considerable number of shallow tube wells. Although emerging number of tube wells succeeded in reducing the number of death from waterborne dieses but unfortunately, it is now established that many of tube wells water contain Arsenic at concentration higher than the safe limit for drinking purpose (RVWRMP, 2004)**.** Presence of arsenic in groundwater in the Terai districts was known for the first time in 1999 from the research work assisted by WHO (Sharma, 1999). Since then there has been a growing concern among the Nepalese scholars towards understanding more on arsenic and its human health impacts.

Elevated level of arsenic in drinking water and arsenic-induced health problems are no doubt imminent in Nepal. Many people who are and have been consuming high concentration of arsenic might be facing high mortality from skin and internal cancers (Adhikari, 2005). It is reasonable to expect that many will develop skin lesions, neurological defects, hypertension, cardiovascular diseases, pulmonary diseases, peripheral vascular diseases and diabetes mellitus. Arsenicosis, or arsenic toxicity, develops after two to five years of exposure to arsenic contaminated drinking water, depending on the amount of water consumption and arsenic concentration in water (UNF, 1999). Most of the tube wells in Terai region of Nepal were installed 5- 15 years ago (Maharjan et.al, 2006). Hence, we are likely to face, perhaps debilitating, and health impacts in years to come if people continue drinking arsenic contaminated water Level of arsenic concentration in western Terai including, but not limited to, Kailali and Bardiya is significant and many of the tube wells have level of arsenic concentration more than permissible limit for drinking water according to Nepalese standard (i.e. 50ppb).

Arsenicosis is recognizable from skin color changes on unexposed part of the body, hyperpigmentation on the chest and upper arms, hard patches on palms and soles of the feet, inability to walk, debilitating pain and watery eyes. It develops after two to five years of exposure to arsenic contaminated drinking water, depending on the amount of water consumption and arsenic concentration in water. Initially, the diffuse melanosis takes place and skin begins to darken first in the palms. Diffuse melanosis leads to spotted melanosis, when darkened spots begin to appear on the chest, back and limbs, although the latter is what is usual among people, and so is taken to be an early symptom. At a later stage, leucomelanosis sets in the body begin to show black and white spots. Keratosis is the middle stage of arsenicosis. The skin, in portions, becomes hard and fibrous; it is as if the body has broken out into hard boils, or ulcers. Diffuse or nodular keratosis on the palm of the hand or sole of the foot is a sign of moderately severe toxicity. Rough, dry skin, often with palpable nodules on hands, feet, and legs means severe toxicity. This can lead to the formation of gangrene, and cancer (Rahman et al., 1999).

Arsenic dissolved in water is acutely toxic and can lead to a number of health problems. Long-term exposure to arsenic in drinking water causes increased risks of cancer in the skin, lungs, bladder and kidney. It also leads to other skin-related problems such hyperkeratosis and changes in pigmentation. Consumption of arsenic also leads to disturbance of the cardiovascular and nervous system functions and eventually leads to death. These health effects, sometimes, collectively referred to as arsenicosis – have been demonstrated in many studies. Increased risks of lung and bladder cancer and of arsenic-associated skin lesions (AASL) have been reported for consuming drinking water with arsenic concentrations equal to or greater than 50 ppb (or µg/l) (WHO, 2001).

The acute toxicity of arsenic compounds in humans is predominantly a function of their rate of removal from the body. Arsine is considered to be the most toxic form, followed by the arsenites (arsenic (III)), the arsenates (arsenic (V)) and organic arsenic compounds. Lethal doses in humans range from 1.5 mg/kg of body weight (diarsenic trioxide) to 500 mg/kg of body weight (Buchet and Lauwerys, 1981). Acute arsenic intoxication associated with the ingestion of well water containing 1.2 mg/l (Feinglass, 1973) and 21.0 mg/l (Wagner et al., 1979) has been reported.

Early clinical symptoms of acute intoxication include abdominal pain, vomiting, diarrhoea, muscular pain and weakness, with flushing of the skin. These symptoms are often followed by numbness and tingling of the extremities, muscular cramping and the appearance of a papular erythematous rash (Murphy et al., 1981). Within a month, symptoms may include burning paraesthesias of the extremities, palmoplantar hyperkeratosis, Mee's lines on fingernails and progressive deterioration in motor and sensory responses (Fennell and Stacy, 1981; Murphy et al., 1981; Wesbey and Kunis, 1981). Signs of chronic arsenicism, including dermal lesions such as hyper-and hypopigmentation, peripheral neuropathy, skin cancer, bladder and lung cancers and peripheral vascular disease, have been observed in populations ingesting arseniccontaminated drinking water (Tseng et al., 1968; Borgono and Greiber, 1972; Hindmarsh et al., 1977; Tseng, 1977; Zaldivar and Ghai, 1980; Valentine et al., 1982; Cebrian et al., 1983). Dermal lesions were the most commonly observed symptom, occurring after minimum exposure periods of approximately 5 years. Effects on the cardiovascular system were observed in children consuming arsenic-contaminated water (mean concentration 0.6 mg/litre) for an average of 7 years (Zaldivar and Ghai, 1980).

Long-term exposure to arsenic in drinking water is causally related to increased risks of cancer in the skin, lungs, bladder and kidney, as well as other skin changes such as hyperkeratosis and pigmentation changes. These effects have been demonstrated in many studies using different study designs. Exposure–response relationships and high risks have been observed for each of these end-points. The effects have been most thoroughly studied in Taiwan but there is considerable evidence from studies on populations in other countries as well. Increased risks of lung and bladder cancer and of AASL have been reported to be associated with ingestion of drinking water at concentrations ≥50 μg arsenic/litre (IPCS, 2001).

1.2 Rationale

Due to increasing extraction of arsenic contaminated groundwater in Terai region is causing health problems in Terai dwellers. Kailali and Bardiya are the mostly affected districts of the western Terai and the study VDCs are severely affected part within those districts. Therefore, People of study area are at risk of arsenicosis. Nepal should be alert to prevent the arsenicosis as an epidemic for which it is important to assess the Arsenicosis symptoms among people of Terai community. Therefore, this study will be significant, as it reveals prevalence of arsenicosis and its awareness among people to prevent melanosis, keratosis within the study area of Kailali and Bardiya districts.

Though arsenic contamination in thousands of tubewells in Nepal were reported, so far only a little published information is available which could sufficiently explore the magnitude of health effects due to chronic exposure to arsenic through tubewell water. Kailali and Bardiya are the most affected districts of western terai of Nepal as per arsenic testing result at March 2007 (DWSS, 2007). Most of the people of Kailali and Bardiya are dependent on the ground water for drinking purpose and the average age of the tubewells in these areas is 5-15 years which verifies the possibility of the arsenicosis in the area. Furthermore awareness on arsenicosis among the risk household is very low, which magnifies the problem of arsenicosis in the study area. The current statistics on prevalence of arsenicosis in these districts is unknown. Hence, the current status of prevalence of arsenicosis is imperative to explore and undertake relevant actions to minimize, if possible alleviate, arsenicosis impacts. Therefore, this study will be significant, as it will reveal the magnitude of the problem of arsenicosis and its awareness among people to prevent Melanosis, Keratosis, skin cancer, and arsenic poisoning.

1.3. Aims and Objectives

1.3.1 General

The general objective of the study is to find out the prevalence of arsenicosis among the risk population in Kailali and Bardiya districts of Nepal.

1.3.2 Specific

To identify arsenicosis symptomatic patients in selected VDCs of Kailali and Bardiya districts

To analyze the symptomatic effects among the people of various socioeconomic status.

To analyze the symptomatic effects among the people of various age group.

To assess the level of awareness about the arsenic and its mitigation among the users of arsenic contaminated drinking water.

1.4 Limitations

- This study is limited to the households selected based upon the information provided by the Department of water supply and Sanitation (DWSS).
- The health survey results reflect the confirmed cases as per WHO flowchart only.
- The greatest weakness of the present study was that nutrition habit of the risk population was not observed directly and we assumed that participants with higher monthly income would have taken more nutritional diet.

CHAPTER-II

LITERATURE REVIEW

2.1 Natural Sources of Arsenic

2.1.1 Earth's Crust

Arsenic is the twentieth most abundant element in the earth's crust (ATSDR, 1998; NAS, 1977). Concentrations of arsenic in the earth's crust vary, but average concentrations are generally reported to range from 1.5 to 5 mg/kg (ATSDR, 1998; Cullen and Reimer, 1989; NAS, 1977). Arsenic is a major constituent of many mineral species in igneous and sedimentary rocks. Among igneous rock types, the highest arsenic concentrations are found in basalts. Sedimentary rocks particularly iron and manganese ores often contain higher average arsenic concentrations than igneous rocks (Welch *et al.,* 1988).

2.1.1.1 Soil and Sediment

Arsenic concentrations in soils depend in part on the parent materials from which the soils were derived, although they may be enriched by other sources, including anthropogenic sources. Typical natural concentration ranges are 0.1 to 40 mg/kg, with an average concentration of 5-6 mg/kg (NAS, 1977). The level of arsenic in soil derived from basalts tends to be higher than in soils of granitic origin, and concentrations of 20 to 30 mg/kg may be found in soils derived from sedimentary rocks (Yan-Chu, 1994). Arsenic may be transferred to surface water and ground water through erosion and dissolution. Because arsenic can be fixed in inorganic and organic compounds in soil, soil may also be a sink for arsenic (EPA, 2000).

Recent anthropogenic arsenic releases may also result in the elevation of arsenic concentrations in surface sediments. Arsenic may also be released from bottom sediments because of microbial action. In soil, the biotransformation of arsenic make arsine gases subsequently volatizing to the environment. In sediment, biologically mediated methylation of arsenates increases the solubility of arsenic, and may increase arsenic concentrations in water (Mok and Wai, 1994).

2.1.1.2 Geothermal Waters

Geothermal water can be sources of arsenic in surface water and ground water. Flow of arsenic-enriched geothermal water from hot springs may result in high concentrations of arsenic in surface water systems (ATSDR, 1998).

2.1.1.3 Other Sources

Natural emissions of arsenic associated with volcanic activity and forest and grass fires are recognized to be significant. Indeed, volcanic activity appears to be the largest natural source of arsenic emissions to the atmosphere. But the relative contributions of volcanic sources, other natural sources, and anthropogenic sources to the atmosphere have not been definitively established (ATSDR, 1998).

2.2 Anthropogenic Sources of Arsenic

From man-made sources, arsenic is released to terrestrial and aquatic environments and to the atmosphere. The anthropogenic impact on arsenic levels in these media depends on the level of human activity, the distance from the pollution sources, and the dispersion and fate of the arsenic that is released (EPA, 2000).

2.2.1 Wood Preservatives

Chromated copper arsenate (CCA) is the most widely used wood preservative. CCA is an inorganic arsenic compound and consists of arsenic, chromium and copper. Different arsenic compounds are used as active ingredients in CCA, including arsenic acid (H_3AsO_4), arsenic pentoxide (As_2O_5), and sodium arsenate (Na_2HAsO_4) (Reese, 1998; 1999).

2.2.2 Agricultural Uses

Past and current agricultural uses of arsenic and arsenic compounds include lead arsenate,arsenic trioxide, sodium arsenate, calcium arsenate, copper acetoarsenite (Paris Green), copper arsenate, CCA and magnesium arsenate in various pesticides, herbicides, insecticides, defoliants, and soil sterilants. Arsenic compounds (Roxarsone and Arsanilic acid) are currently used in raising livestock as feed additives and for disease prevention (Azcue and Nriagu, 1994). The, most widely applied Organoarsenical pesticide is Monosodium Methanearsonate, which is used to control broadleaf weeds (Jordan et al., 1997).

2.2.3 Industrial Uses and Releases

Arsenic and arsenic compounds are used in a variety of industrial applications. Arsenic metal is used in the production of posts and grids for lead-acid storage batteries, and is used in the formulation of some copper alloys (Reese, 1998). Crystalline gallium arsenide is a semiconducting material used in computers, optoelectronic devices and circuits, and other electronic applications. Industrial processes including the burning of fossil fuels, combustion of wastes (hazardous and non-hazardous), pulp and paper production, glass manufacturing, and cement manufacturing can result in emissions of arsenic to the environment (USEPA, 1998). Coal-burning power plants may emit aerosols and fly ash that contain arsenic (Yan-Chu, 1994). Waste disposal practices also may have impact upon arsenic concentrations in ground water and surface water at waste disposal sites (EPA, 2000).

2.2.4 Mining and Smelting

Mining of the arsenic content rocks and minerals for various purposes may emit arsenic to the atmosphere. Sulfide-bearing rocks are often mined for gold, lead, zinc, and copper, and arsenic is frequently found as an impurity in the sulfide ores of these metals. In mining areas, the arsenopyrite (FeAsS), mineral orpiment, realgar, and arsenic-rich iron oxides are the sources of dissolved arsenic (Welch *et al.,* 1988).

2.3 General Health Effects

Arsenic has long been associated with toxic effects, producing marked impacts on health after both oral and inhalation exposure. Effects range from acute lethality to chronic effects, such as cancer and diseases of the vascular system.

2.3.1 Acute effects

Acute Arsenical poisoning due to inhalation is exceedingly rare in the workplace. When it does occur, it produces respiratory tract symptoms (cough, chest pain and dyspnea), giddiness, headache, and extreme general weakness, followed by gastrointestinal symptoms including epigastric pain, vomiting and diarrhea.Symptoms within 30 minutes, but delayed for hours if ingested with food. Absorbed usually through Gastro Intestinal Tract, but also inhaled or through the skin. Other symptoms may include dehydration, intense thirst, burning lips, dysphasia, pain in extremities and muscles, weakness.

2.3.2 Chronic Effects

Chronic signs of toxicity in workers exposed to Arsenic compounds are related chiefly to the skin, mucous membranes, gastrointestinal and nervous systems, and far less commonly to disorders of the circulatory system and liver chronic poisoning from inhalation exposure have been described as having three phases based on signs and symptoms.

Chronic inhalation of inorganic Arsenic compounds is the most common cause of industrial poisoning. The sequence of chronic poisoning involves weakness, anorexia, hepatomegaly, jaundice, and gastrointestinal complaints, followed by conjunctivitis, irritation of throat and respiratory tract, perforation of the nasal septum, hoarse voice, hyperkeratosis, hyperpigmentation, eczemoid and allergic dermatitis. Numbness, burning, and tingling of the hands and feet, muscle fasciculations, gross tremors, ataxia, incoordination, and mental confusion have also been observed.

Final phase consists of peripheral sensory neuropathy of hands and feet, motor paralysis. Certain Arsenic compounds are known to be human carcinogenic. Chronic exposure either in occupational setting or through drinking contaminated groundwater carries increased risk of skin, lung, and bladder cancers.

First phase: The worker complains of weakness, loss of appetite, some nausea, occasional vomiting, a sense of heaviness in the stomach, and some diarrhea.

Second Phase: The worker complains of conjunctivitis, and a catarrhal state of the mucous membranes of the nose, larynx and respiratory passages. Coryza, hoarseness, and mild tracheobronchitis may occur. Perforation of the nasal septum is common, and is probably the most typical lesion of the upper respiratory tract in occupational exposure to Arsenical dust. Skin lesions, eczematoid and allergic in type, are common.

Third Phase: The worker complains of symptoms of peripheral neuritis, initially of hands and feet, which is essentially sensory. In more severe cases, motor paralyses occur; the first muscles affected are usually the toe extensors and the peronei. In only the most severe cases will paralysis of flexor muscles of the feet or the extensor muscles of hands occur.

2.4 Treatment of Arsenicosis

It is suggested that the first stage in treating arsenicosis should be the immediate cessation of consumption of arsenic contaminated water. Once this has been achieved the emphasis should be on the provision of a diet high in protein (preferably meat) and vitamins, to aid the methylation of inorganic arsenic in the body. The chelating agents dimercaptopropane sulphonate and dimercaptosuccinic acid are recommended as treatment drugs.

2.4.1 Chelation Therapy

Recently chelation therapy for the treatment of Arsenicosis is considered to be the specific therapy for relief of systemic clinical manifestations and reduction of arsenic stores in the body, decreasing subsequent cancer risk.

2.4.2 Nutritious Diet and Vitamins

Symptoms are improved by good diet and vitamins. High protein diet helps in the clearance of inorganic arsenic by increased methylation and protects against toxic effect of arsenic. The antioxidants vitamins - A, E and C play an important role for management of cases. Vitamin C reduces the toxicity of arsenic and deficiency of vitamin A increases sensitivity to arsenic.

Excessive intake of vitamin A may produce chronic toxicity in the body such as appetite loss, dry skin, bone and joint pain, enlarged liver and spleen, abnormal skin pigmentation. Vitamin E is relatively non-toxic. Adults appear to be able to tolerate dose as high as 1000 IU per day. Excessive dose of vitamin C, 2gm or more may produce side effects.

People should be advised to take more protein and vitamin rich food like beans, peas, pulse, lentils, wheat, soybeans, green and leafy vegetables.

2.4.3 Other Symptomatic Treatment

Keratosis of palms and soles can be treated by local application of keratolytic ointment - 20% Urea and 10% to 20% Salicylic acid in cream or Vaseline. Cryosurgery can also be done to remove keratosis. Treatment of associated fungal infection with ointment and medicine also improve the cases.

To know the effect of providing safe water to the affected people, in India a cohort of 24 patients of chronic arsenicosis were reexamined after drinking arsenic free water for a period varying from 2 -10 years. These people were drinking arsenic contaminated water (0.13 - 2.0 mg/l) earlier for 4 to 15 years. Partial improvement of pigmentation and keratosis was observed in 45 and 46% of cases respectively (Source: Dhaka Community Hospital/Hosted: June, 2001)

2.5 Prevention and Control of Arsenicosis

The most important remedial action is prevention of further exposure by providing safe drinking- water. The cost and difficulty of reducing arsenic in drinking water increases as the targeted concentration lowers. It varies with the arsenic concentration in the source water, the chemical matrix of the water including interfering solutes, availability of alternative sources of low arsenic water, mitigation technologies, amount of water to be treated, etc.

Control of arsenic is more complex where drinking-water is obtained from many individual sources (such as hand-pumps and wells) as is common in rural areas. Low arsenic water is needed for drinking and cooking. Discrimination between high-arsenic and low-arsenic sources by painting the hand-pumps (e.g. red and green) can be an effective and low cost means to rapidly reduce exposure to arsenic when accompanied by effective health education.

Alternative low-arsenic sources such as rain water and treated surface water may be available and appropriate in some circumstances. Where low arsenic water is not available, it is necessary to remove arsenic from drinking water:

The technology for arsenic removal for piped water supply is moderately costly and requires technical expertise. It is inapplicable in some urban areas of developing countries and in most rural areas world-wide.

New types of treatment technologies, including co-precipitation, ion exchange and activated alumina filtration are being field-tested.

There are no proven technologies for the removal of arsenic at water collection points such as wells, hand-pumps and springs.

Simple technologies for household removal of arsenic from water are few and have to be adapted to, and proven sustainable in each different setting.

Some studies have reported preliminary successes in using packets of chemicals for household treatment. Some mixtures combine arsenic removal with disinfection. One example, developed by the WHO/PAHO Pan American Center of Sanitary Engineering and Environmental Sciences in Lima, Peru (CEPIS), has proven successful in Latin America.

2.6 Previous Researches on Arsenicosis from Nepal

DWSS and WHO (1999) carried out the first Nepalese studies on arsenic in groundwater followed by Nepal Redcross Society (NRCS) and Japan Redcross Society (JRCS) (2000). Both studies provided evidence of arsenic contamination in Terai region of southern Nepal. Furthermore, an initial health survey in 2001-2002 found evidence of arsenic-related dermatosis and elevated amounts of arsenic in human hair and nail samples in four districts where tube well drinking water contained arsenic above 50 ppb (parts per billion). This initial evidence of arsenic contamination and associated health effects led to the creation of the National Arsenic Steering Committee (NASC) to help coordinate efforts by government and non-government agencies to address the potential problems of arsenic contamination in the rapidly growing region of southern Nepal.]

Sharma (1999) carried out study on possible contamination of groundwater with arsenic in Jhapa, Morang and Sunsari, Eastern Terai. Out of 268 water samples tested for arsenic, 244 of them were found safe (below WHO guideline, 10 ppb) 2 of them showing a concentration level higher than 50 ppb. Most of the contaminated samples lie within active flood plains near Koshi River.

Tandukar (2000) conducted a study to explore the severity of arsenic contamination of groundwater in Rautahat district of central Terai in Nepal. The results shows that some samples exceeded WHO drinking water quality standard and few of them exceeded India and Bangladesh standards. High arsenic is found to be associated with high iron content. However, not all the groundwater samples with iron contain arsenic. Arsenic contamination is found to be higher in shallow aquifer and most of the contaminated tubewells are located in active flood plain of River Bagmati. It is found that the concentration of arsenic in groundwater of the study area does not remain constant throughout the year. In fact, concentration of arsenic in the tubewells installed in active flood plain of River Bagmati was observed that villagers were using arsenic contaminated water without taking any precautions and without having any knowledge about the severity and ultimate effects of arsenic. The potential arsenic contaminated areas have also been identified within the study area. Arsenic removal techniques were also reviewed and best available method is suggested for use by the rural people.

NRCS, JRCS and ENPHO (2001) collaboratively conducted a household survey on the health impact of Arsenic contaminated ground water in parsa under the drinking water quality improvement program. A simple cross-sectional and descriptive study of the exposed population was done in Parsa District to assess the arsenic related health problems and to recommend appropriate measures to prevent or contain the problem. A total of 473 households with 3,579 populations were surveyed with a questionnaire. Out of that, a population of 2,732 present at the time of the survey was observed to detect the arsenicosis-like skin problems. The duration of exposure to arsenic contamination from the tested 49 tube wells (with arsenic content in the water to be more than 50 ppb) ranged from 0.5 to 15 years with a mean duration of a little over 5 years. Overall prevalence of the arsenicosis among the exposed population was 1.8 percent. Males were more often affected than females. Similarly the prevalence among the elderly population was significantly higher, ranging from 6.7 to 8.7 percent, suggesting cumulative nature of chronic arsenic poisoning. Main skin lesions detected were spotted or disseminated melanosis or spotted or disseminated keratosis in palms, soles and trunk. Keratotic changes were more common in palms or soles while melanotic ones were observed relatively more frequently in the trunk. However, the skin changes observed were at an early stage. All 40 tests of laboratory confirmation all cases showed arsenic positive in either hair or nail or both. Recommendations made were to continue an ongoing water testing and survey or research programs, replacement of water supply with non-contaminated sources (surface water or deep bored tube-wells) or containment programs, appropriate nutritional education, palliative treatment and follow-up observation of detected cases.

Sah *et al.* (2003) carried out a study on possible natural sources of arsenic poisoning of ground water in Terai Plain of Nepal and their major findings. Several natural sources of arsenic have been identified from the country. Arsenic minerals-Arsenopyrate from polymetallic Pb-Zn deposits of Central Nepal. Sulphide minerals – Pyrite, Sphalerite, Galena from Ganesh Himal Pb-Zn Deposits Iron ore minerals and sediments – Hematite ore deposits of phulchoki, Goethite Fe-concretion and Fe-coatings from siwaliks of Amlekhganj area and quartery sediments of terai plain Rocks – Fe-sandstone, quartzite and shale/slate from Midland and Tosh Groups, bituminous shale of Dang Area. Studied aquifer sediments of Terai Plain do not contain sulphide minerals like pyrite, arsenopyrite, galena and sphalerite but it contains Fe-concretions, Fe-coatings rich in arsenic and possible, they represent the immediate source of arsenic in groundwater of Terai Plain Studied river waters along the Mahendra Highway are found to be safe, not contaminated in arsenic. So, there is less possibility of groundwater contamination by arsenic from the recharge zone. In all studied sites of the five districts, the contaminated groundwater are tapped from confined aquifers. So, there is less possibility of groundwater contamination from top soil. Most possible, initially the arsenic was released from the exposed area of sulphide minerals of polymetalic deposits due to oxidation. Then it was adsorbed by ferrous- or ferric ions and precipitated together with iron in the form of ferruginous concretions or coatings on grain surface. The precipitated Fe-concretions and coatings get themselves below water table and under reducing regime release arsenic to groundwater together with iron. A strong positive correlation of oxalate extracted arsenic and iron from the studied aquifer sediments is in favor of this concept.

NRCS and ENPHO (2003) made a collaborate study on Arsenic status of the tube wells installed by NRCS in Rautahat district which is a cross-sectional, descriptive type. Out of total 2144 tube wells installed by NRCS in 56 Village Development Committee (VDCs) of the district, altogether 1785 tube wells have been tested. Of this 815 tube wells from 25 VDCs have been considered for the study, of which 157 tube wells are found to have Arsenic concentration above acceptable level (>50 ppb). The study was carried out from October 2001 to May 2002 with the objectives of identifying Arsenic related health problems, analyzing mitigation measures adopted by NRCS and providing appropriate strategy as recommendations for prevention and management of arsenicosis. A total of 1,338 households with 7,441 persons exposed to Arsenic contaminated drinking water (> 50 ppb) for more than 2 years have been considered for the study. The concentration of Arsenic in the water of the tube wells ranged from 50 to over 200 ppb. A total of 141 households with their 243 members have reported of skin problems such as itching, pain, itching and pain combined, inconvenience and skin change. Of those family members, 167 are confirmed to have symptoms, melanosis on the trunk and Keratosis on the palm were common. The prevalence rate of Arsenicosis was 2.2% among the exposed population. The highest prevalence rate was found in the age group of above 65 years, whereas the lowest value occurred in the age group of 15-49 years. The prevalence rate was found higher in the males than the females. The prevalence rate in the areas of Rautahat district is much less compared to 31.1% in arsenic affected areas of Bangladesh. Yet, the groundwater with shallow tube well is the main source of drinking water in the district exposing the population potentially at risk of arsenic contamination.

Kanel *et al.* (2004) conducted a study entitled "Arsenic Contamination in Groundwater in Rautahat, Nepal". This study is directed to investigate the occurrences of arsenic contamination and its mechanism to release in groundwater in Gaur Municipality, Rautahat District, Nepal. In the observation, the groundwater was found to be rich in iron, manganese and bicarbonates, which support iron reduction hypothesis as the main mechanism of mobilization of arsenic in the groundwater. The arsenic concentration was varied from 0 to 62 μg/L in groundwater samples from shallow tubewells. Among analyzed samples, 2 % exceeded 50 μg/L concentration and 36 % were between 10-50 μg/L concentrations and rest of samples (62%) were below 10 μg/L concentration. However, the WHO guideline of maximum concentration limit of arsenic in groundwater is 10 μg/L for drinking purpose. The high arsenic concentration found in large number of tubewells indicates that several million people are consuming arsenic contaminated water (without any pretreatment) at serious risk of arsenic poisoning. However, there is no counter treatment of arsenic diseases and arsenic remediation is the only one option to save the lives of millions of people.

Ahamad *et al*. (2004) reported that although arsenic contamination of groundwater has been detected recently in the Terai region of Nepal, scarce data have been available regarding the possible health effects of the contamination. A study was carried out in two rural villages of Nawalparasi district, where the existence of arsenic contamination has been reported. Almost all tube wells in one of the two villages (Goini, G) exceeded (ranging from 0.104 mg/L to 1.702 mg/L) the maximum permissible limit for arsenic in drinking water in Nepal (0.05 mg/L), and only a few tube wells (19.5%) in the other village (Kunuwar Big, KB) were below this level (0.004 mg/L to 0.972 mg/L). Prevalence rates of Arsenicosis diagnosed on the basis of the presence of dermatological manifestations were 11.3% (56 out of 495 examined) and 6.5% (34/525) in G and KB, respectively, with an overall prevalence rate of 8.9%. In terms of gender, the prevalence rate was higher in males (11.5%; 61/531) than in females (5.9%; 29/489), supporting previous observations including our own. Most (71.1%) of the identified patients were 20-49 years old, and the prevalence rate appeared to be higher among those in their 30s or 40s in the both sexes. The youngest patient was 10 years of age. All the patients were either in the mild or moderate stage of the disease and most (78.9%) were in the mild stage. Melanosis with some other manifestations was observed in 95.6% of the patients, while keratosis was found in 57.8%. Leucomelanosis without any other manifestations, which has not been reported either in Bangladesh or India, was observed in 3.3% of the identified patients. Only one patient had Bowen's disease.

World Bank (2005) mentions that the present estimation of number at risk population from arsenic in drinking in Nepal is 0.3 million which is 3.4% of the total population. Similarly, the number of arsenicosis patients identified so far counts 8,600.

Maharjan *et al.* (2005) conducted a community-based, dose-response study on Arsenic contamination in three communities in Terai in lowland Nepal. The arsenic concentration of all the tubewells in use (n=146) and the prevalence of AASL among 1,343 (approximately 80% of the inhabitants) subjects indicated the existence of a highly contaminated area in Terai. It was found that overall prevalence of Arsenicosis among the subjects$\geq$ 15 years old was 6.9%, which was comparable to those found by the same examiner in arsenic-contaminated areas in Bangladesh, and that males had prevalence a twice as high as females, which could not be explained by the difference in the exposure level.

Adhikari (2005) Conducted research entitled "study of Arsenic contamination in ground water and its effects in human health in Balchanpur, Dumeria," in Rautahat District, one of the most arsenic affected areas, of Nepal. The study was carried out by using ENPHO Kit Method and results were cross-checked in the laboratory by Arsine Generator method. Arsenicosis patients were diagnosed with the help of visible symptoms skin manifestations using standard WHO field guidelines (WHO 2004). During the studied period of Baisakh month of 2062, out of total 144 people from 31 families, 11 people (7.63%) were found to be infected with Arsenicosis. Among 63 males, 10 (15.87%) had melanosis in trunk, where as, out of 81 females, 1 (1.23%) had melanosis in limb. The highest number of patients (5 out of 11, 45.45%) were found to be consuming the water of the tube well for 10 years. There was significant difference among different arsenic contaminated tube wells in different ward numbers of Dumariya VDC (χ^2=20.59, degree of freedom=8, P< 0.05). However, there was statistically no association of depth of tube wells and arsenic contamination (χ^2 =9.67, degree of freedom= 16, P >0.05). Positive correlation was found between ENPHO arsenic kit test and laboratory method (Arsine Generator) with the coefficient of determination (R^2) = 0.9963. From the Dumeria Balchanpur litholog analysis, Arsenic testing in groundwater of the site showed that aquifer lying at 10-11 m and 16-18 m were contaminated, whereas, aquifer lying at 36-45 m was safe from arsenic contamination.

2.7 Previous Researches on Arsenicosis from Abroad

Cebrian *et al.* (1983) conducted a cross-sectional study of skin lesions in two towns in Mexico. The average arsenic concentration of water samples in the exposed town was 0.411 mg/litre; the average concentration in the control town was 0.005 mg/litre. The subjects examined were selected for examination by systematic sampling of the populations in the two towns: 296 individuals from the control population of 1488 were physically examined. In the exposed town, there were 52 cases (17.6%) of hypopigmetation, 36 cases of hyperpigmentation(12.2%), 33 cases (11.2%) of palmoplanatar keratosis, 15 cases (5.1%) of popular keratosis, and 4 cases(1.4%) of ulcerative zones(skin cancer). In the control town, there were 7 cases(2.2%) of hypopigmentation, 6 cases(1.9%) of hyperpigmentation, 1 case(0.3%) of palmoplanatar keratosis, no cases of popular keratosis, and no cases of ulcerative zones(skin cancer). The prevalence of all the skin lesions was significantly elevated in the exposed town ($p<0.001$, with the exception of ulcerative zones which had $p=0.04$) and was generally found to increase with age. Non-specific symptoms (e.g. nausea, epigastric pain, colic abdominal pain, diarrhea, headache, and edema)

Wu *et al.* (1989) investigated the mortality in residents of 42 villages in southwestern Taiwan from vascular diseases and cancer. The age-adjusted mortality rates from lung, liver, kidney and bladder cancer, as well as those from skin cancer, showed an association with the village median well-water arsenic concentration in both men and women.

Chang *et al.* (1991) reported that Blackfoot disease, an endemic peripheral vascular disorder confined to a limited land area on the southwest coast of Taiwan has been related to the consumption of high levels of arsenic found in the artesian well water

Smith *et al.* (1992) explained the ingestion of arsenic, both from water supplies and medicinal preparations, is known to cause skin, liver, lung, kidney, and bladder cancer and that the population cancer risks due to arsenic in U.S. water supplies may be comparable to those from environmental tobacco smoke and radon in homes.

Ferreccio *et al.* (1998, 2000) made a hospital-based case-referent study in northern Chile (Regions I-III) in which drinking-water arsenic exposure was compared between 151 lung cancer cases and 419 referents (167 with cancer and 242 with other diseases). Drinking-water arsenic concentration was assessed from the records of information on residence, health and employment history from a questionnaire. The Odd Ratio (OR) for lung cancer, adjusted for age, sex and smoking (ever/never), was related to drinking-water arsenic levels in the five exposure strata, and reached statistical significance in the highest exposure stratum.

Mazumder *et al.* (1998) investigated the relationship between skin keratosis and hyperpigmentation and consumption of arsenic-contaminated drinking water in a cross-sectional study of a population (7683 participants) in West Bengal (India). They were from areas of both high and low arsenic-exposure. Comparison by dose per body weight found that men had roughly 2-3 times the prevalence of both keratosis and hyperpigmentation compared to women apparently ingesting the same dose of arsenic from drinking-water. Subjects below 80% of their body weight for their age and sex had a 1.6-fold (CI 1.0-2.4) increase in the prevalence of keratosis, suggesting that malnutrition may play a role in increasing susceptibility. No such difference was observed for hyperpigmentation. Twelve subjects with keratoses, suggesting that malnutrition may play a role in increasing susceptibility. No such difference was observed for hyperpigmentation. Twelve subjects with keratosis drank water containing<100 µg As/liter; 29 with hyperpigmentation drank water containing< 100 µg As/liter.

Tondel *et al.* (1999) examined 1481 subjects ≥30 years of age in four villages in Bangladesh. All were determined to have had a history of arsenic exposure through arsenic-contaminated drinking-water. Arsenic concentrations in the drinking-water ranged from 10 to 2040 µg Arsenic/litre. Of the 1481 people examined, 430 were found to have to have skin lesions (pigmentation changes to keratosis). The age-adjusted prevalence rate of skin lesions was found to increase from 18.6 per 100 in the lowest exposure category (≤ 150 µg As/liter) to 37.0 per 100 in the highest exposure category (> 1000 µg As/liter) for males and from 17.9 per 100 in the lowest exposure category to 24.9 per 100 in the highest exposure category for females. The trend was statistically significant for both males and females. When the exposure was considered by dose (µg /liter), there was also an increase in the age-adjusted prevalence rate of skin lesions for both males and females across dose groups, the trend being statistically significant.

Safiuddin *et al.* (2001) presented an overview of groundwater arsenic contamination in Bangladesh. This study highlights the causes and mechanisms of arsenic contamination in groundwater and effects of arsenic contamination on human health along with several remedial measures.

Erica Weir (2002) explained the epidemiology of Arsenicosis (skin manifestations of arsenic poisoning) and skin cancer. Males exposed to more than 600 µg/L of arsenic face a risk of bladder cancer that is 28.7 times higher than the risk in the general Taiwanese population.

Milton *et al.* (2002) carried out a study on respiratory effects and arsenic contaminated well water in Bangladesh. A prevalence comparison study of respiratory effects among subjects with and without arsenic exposure through drinking water was conducted. These results add to evidence that long-term ingestion of arsenic exposure can cause respiratory effects.

Mitra *et al.* (2002) carried out study on Arsenic-related health problems among hospital patients in Southern Bangladesh. They found out that the mean arsenic concentration in water was significantly associated with the severity of disease. Body mass index (BMI) correlated inversely with the duration of disease after controlling for age.

Mukherjee *et al.* (2003) reported a large number of people of West Bengal, India are endemically exposed to arsenic contaminated groundwater. They conducted studies on neurological involvement in patients of arsenicosis; Peripheral neuropathy was the predominant neurological complication in these patients. Prognosis was favorable in mild and early-diagnosed cases of neuropathy whereas most of the other more severe and late diagnosed cases showed slow and partial recovery or even deterioration. Outcome in neuropathic patients of arsenicosis and long term toxic neurologic effects yet unexplored and unknown remain as matters of future concern requiring close monitoring.

Hassan *et al.* (2005) reported that besides its toxicity, groundwater arsenic contamination creates widespread social problems for its victims and their families in Bangladesh. They found that patients' experiences reveal severe negative social impacts, and a sharp difference of perceptions about arsenic and social issues between Arsenicosis patients and unaffected people.

Sarkar *et al.* (2005) conducted a cross-sectional survey in West Bengal for finding out social dimension of chronic arsenicosis. Out of total of 7678 arsenic exposed individuals, 410 were found to have single or multiple manifestations and association between arsenic exposure level and the severity of manifestation was found ($p<0.05$). Severe manifestations, prevalence, and mortality rate were found more among lower socioeconomic status (SES) ($p<0.005$ to 0.05). Lower age group was mostly found among poorer sections of the community (95%CI, 17.8, 25.7 & 36.3, 48.9, lowermost and uppermost SES respectively). Households from higher SES could afford to shift to an alternative arsenic-free water source, and many had experienced an improvement in symptoms. Landless agricultural laborers were exposed to higher levels of arsenic. Severe forms of manifestations were found to be associated with low BMI ($p< 0.05$). Low BMI was associated with lower SES ($p< 0.005$), which was in turn associated with quality and quantity of food intake. Males had higher exposure levels prevalence and mortality rate, severity and duration of manifestations (95%CI, 4.1-6.8 & 2.8, 4.3, males and females respectively), Younger age group (95%CI, 33.5 37.8 & 37.1 39.4, males and females respectively). Marriage was found to be another important determinant of the gender differential in arsenicosis. Higher SES had easier accessibility to health services. There was a gender disparity regarding treatment seeking.

Hossain et al. (2005) conducted a research "entitled manifestation of arsenicosis patients and factors determining the duration of arsenic symptoms in Bangladesh". This study analyzed 1482 arsenicosis patients living in 6 of 496 upzilas (sub-districts) of Bangladesh, who were identified through household screening and then confirmed by a trained medical team headed by medical officer. Melanosis was common (97%) among them but about two-thirds (68.7%) of the patients were suffering from Keratosis. Average age was 36 years and average duration of arsenic symptoms was 3 (median) years. About 50% of the patients had been drinking tube well water more than 24 years. Melanosis was significantly associated with younger patients ($p=0.031$), shallower tube well ($p= 0.005$), and complication of conjunctivitis ($p< 0.001$). Keratosis was also significantly associated with older age ($p= 0.022$), shallower tube well ($p< 0.001$), complication of conjunctivitis ($p< 0.001$), bronchitis ($p< 0.01$), loss of appetite ($p< 0.001$), and wasting ($p<0.001$). Duration of arsenic symptoms was significantly associated with older age ($p< 0.001$), male ($p=0.002$), married ($p< 0.001$), smoking ($p=0.002$), longer duration of consuming tube well water ($p< 0.001$), complication of conjunctivitis ($p=0.002$), loss of appetite ($p< 0.001$), wasting ($p=0.006$), and social problem faced having arsenicosis ($p= 0.040$). Multivariate OR and 95% confidence interval (CI) indicated that keratosis (OR = 2.00; 95% CI: 1.56-2.56) was significantly associated with longer duration of arsenic symptoms; loss of appetite (OR=1.40; 95% CI 1.12-1.74) was a significant complication for longer duration. Similarly smoking (OR= 1.33; 95% CI: 1.06-1.68) was positively associated with longer duration of arsenic symptom. These findings help to understand about the factors that may affect the severity condition of the patients through prolongation of arsenic symptoms.

Rahman *et al.* (2005) carried out an in-depth study in Rajapur, an arsenic-affected village in West Bengal, India to determine the degree of groundwater contamination with arsenic and the impact of this contamination on residents. The flow injection hydride generation atomic absorption spectrometry (FI-HG-AAS) method was used to measure arsenic concentrations in water and biological samples. Out of a total of 336 hand pumped tube wells in Rajapur, 91% (307/336) contained arsenic at concentration s >10 μg/l, and 63% (213/336) contained arsenic at >50 μg/l. The type of arsenic in groundwater, the variation in concentrations of arsenic as the depth of tube-wells changed, and the iron concentration in the wells were also measured. Altogether 825 of 3500 residents were examined for skin lesions; of these, 149 had lesions caused by exposure to arsenic. Of the 420 biological samples collected and analyzed, 92.6 %(389) contained arsenic at concentrations that were above normal. Thus many villagers might be sub clinically affected. Although five arsenic filtering devices had been installed in Rajapur, it appears that villagers are still exposed to raise concentrations of arsenic in their drinking-water. Detailed village-level studies of arsenic-affected areas in West Bengal are required in order to understand the magnitude of contamination and its effects on people. Villagers are ill-informed about the dangers of drinking arsenic-contaminated water. The contamination could be brought under control by increasing community awareness of the dangers and implementing proper watershed management techniques that involve local people.

Lu, (1990) found a clear dose-response relationship between exposure to arsenic and the frequency of dermal lesions, “blackfoot disease” (a peripheral vascular disorder) and skin cancer. However, several methodological weaknesses (e.g., investigators were not “blinded”) complicate the interpretation of the results. In addition, the possibility of other causes of blackfoot disease (e.g., humic acids in artesian well water) were not considered.

CHAPTER III

APPROACHES AND METHODOLOGY

The study will adopt mainly three approaches during its course of preparation. First, it systematically will include selection of communities through rigorous review of relevant documents and statistics related to arsenic contamination in the study districts. Second, in order to assess the grass root situation of exposure and level of awareness, the study will conduct questionnaire survey at each selected communities. Third, this study will include dermatological manifestation of arsenicosis cases at risk households through conduction of health survey.

3.1 Study Design

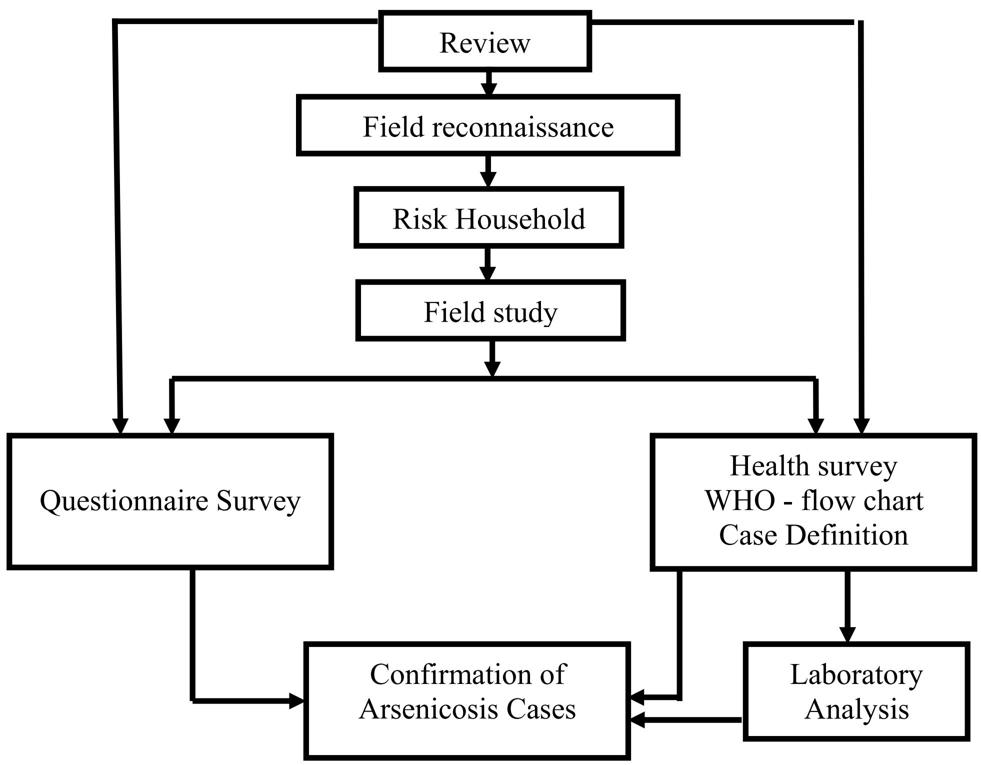


Figure: 3.1 Schematic flow sheet diagram of the study

3.2 Selection of Communities

Considering the comprehensive nature of the data to be collected only few communities with highest prevalence of arsenic contaminated tubewells was selected as project site. Selection of VDCs was made on the basis of blanket testing data of arsenic contamination provided by Department of Water Supply and Sanitation Program (DWSS). Two VDCs from each of the two district including Thapapur and Sadepani form Kailali and Mohamadpur and Jamuni from Bardiya. Cluster sampling method was applied for the selection of communities within the selected VDCs.

3.3 Study Area

3.3.1 Bardiya District

Bardiya District, one of the seventy-five districts of Nepal, is part of Bheri Zone and is headquartered at the city of Gularia. The district covers an area of 2,025 km² and lies west of Banke district, south of Surkhet district, east of Kailai district. To the south lies Uttar Pradesh in India. According to the 2001 census the population was 382,649. The literacy rate of Bardiya constitutes 45.7% with 55.5% for male and 35.9% for female. The adult literacy rate (>15years) drops to 39.4% including 50.7% for male and 28.0% for female (CBS, 2001).

It is fertile plain land covered with agricultural land and forest. The majority of the people living in this district are farmers. The district headquarters, Gularia lies on the Babai River. The Karnali, one of the largest rivers of Nepal, divides into many branches when it reaches the plain and flows through Bardiya. The western branch of the Karnali forms the boundary between Bardiya and Kailali districts. The eastern branch of the Karnali is called the Geruwa. The endangered Gangetic dolphin was often seen in its waters but dolphin population in the rivers of Bardiya have dwindled sharply in recent years.

In the early twentieth century, Bardiya was covered with forest and was sparsely populated with Indigenous tribal people called Tharus. Later on, Nepali-speaking hill people also migrated into Bardiya. At present, thru majority of people living in Bardiya are Dangora Tharus. They have their own language. Sonaha, also tribals of Bardiya, who live near by the Karnali River, live by extracting gold from the sands of the river.

3.3.2 Kailali District

Kailali District, a part of Seti Zone, is one of the seventy-five districts of Nepal, a landlocked country of South Asia. The district, with Dhangadhi as its district headquarters is situated between 28'-22' to 59' N Longitude and 80'- 15 to 81- 15' E Latitude ranging in altitude from 109 to 1957 meters. Climate of Kailali district is Tropical and Sub Tropical. Kailali covers an area of 3,235km² and lies West of Bardiya district, South of Dadeldhura and Doti district, South west of Achham and Surkhet district, East of Kanchanpur district and North of Uttar Pradesh of India. Kailali has a population of 616,697 according to the census of 2001 with population growth rate of 4.95%. Kailali Ranks 52nd position according to the Human Development Index, 1998. Dhangadhi is a center of attraction of not only Kailali district but of whoel seti zone. The place is facilited with all kind of necessay needs. The district has two municipalities and 42 VDCs.

Rich in forest resources, Kailali district mainly holds plain area with a small hill area of Seti zone. The Karnali flows in the east making narrow valleys bordering between Kailali, Surkhet and Bardiya districts. The district is a corridor for The Royal Shukla Phanta Wildlife Reserve and Royal Bardiya National Park. A number of micro watersheds fall in Karnali. The Siwalik range, which divides the south plain and northern hill area, is fragile. Major Drainage: Karnali, Kandra, Thuligaad, Rora, Gauriganga, Khutiya. The rivers cause devastating floods each year during monsoon; rivers like Kandra cut hundreds of hectares of cultivated lands and destroy nearby settlements. Most of the population who has migrated from different parts of the country, as well as the Tharu indigenous community occupies significant position among different caste classes. The literacy rate of Kailali district is 52.6% varying from 41% in female to 64% in male. The adult literacy rate (>15years) drops to 46.5% including 60.6% in male and 32.3% in female (CBS, 2001).

Kailali is rich in wetlands like Ghodaghodi Lake and a number of seasonal lakes. The Ghodaghodi Lake reserves numerous flora and fauna species. It is considered as a paradise of migratory birds where 240 species of birds have been recorded. But, human activities have seriously threatened the habitat of the birds and other species.

3.4 Literature Review

Literatures cited on different books, Journals, reports, dissertations and available on the electronic media were reviewed to gather additional and required information to support the primary data.

3.5 Questionnaire Survey

The structured questionnaire, mostly with open-ended questions was developed (annex I). The questionnaire was pre-tested in 5 households from each of the districts and improvement was made as per the outcomes of pre-testing. Questionnaire survey method was conducted in each risk households of the communities under study to gather supporting information on prevalence of arsenicosis including SES, level of knowledge on arsenicosis, consumption of arsenic contaminated water and duration of exposure. Similarly, unstructured questions were asked during the interview for making the information more clear and transparent. The questionnaire was filled up directly by researcher's self through the interviews with the household members especially female as they are the primary users of the contaminated water.

3.6 Health Survey

3.6.1 Selection of subjects

In Kaliali district total number of household examined were 159 which consists of 25 percent of the total risk households (i.e. 602 households, residence of which are consuming water containing arsenic level 50ppb or more) whereas it was 61 in Bardiya district which was 100 percent of the total risk household. Total number of respondents in Kailali was 898 where as it was 413 for Bardiya district. Visitors or guest in the household were excluded in the study.

3.6.2 Examination for skin manifestation

Health survey was conducted among each member of the risk households within the selected communities. Arsenicosis cases were detected based on dermatological manifestation through direct observation of the limbs, sole, palm, trunk and chest and exposure history of arsenic contaminated water. Probable cases of arsenicosis were confirmed with the help of WHO Flow Chart: Case Definition Algorithm (annex IV) and medical personnel who had experience on diagnosing arsenicosis. Results obtained were noted on the health survey data sheet (annex III) as Melanosis, Keratosis, Cancer and others on the basis of following symptoms.

3.6.2.1 Pigmentation changes (Melanosis)

- Fine freckled or spotted hyperpigmentation pattern on trunk and extremities.
- Diffuse or generalized hyperpigmentation.
- Rounded hypopigmented of depigmented macules on a normal or hyperpigmented background (leukomelanosis; raindrop pigmentation).
- Localized or patchy pigmentation, especially at palm and sole (less common).
- Pigmentation of mucous membranes (oral mucosa), usually in combination with other changes (less common).

3.6.2.2 Keratosis: Mostly characterized by thickening of palms and soles, alone or in combination with nodules that can both be further sub-categorised as follows.

- Mild keratosis- Slight thicking or minute papules (less than 2 mm) on the palms and soles often associated with grit-like texture that may be primarily detectable by palpation.
- Moderate keratosis- Multiple, raised keratotic nodules (>2 to 5 mm), appearing mainly or exclusively in a symmetric distribution on the palms and soles.
- Severe keratosis- Large discrete or confluent keratotic elevations (>5 mm) on the palms and soles, with nodular, wart-like or horny appearance. Less commonly may also appear on the dorsum of the extremities and trunk.
- Diffuse thickening of palms and soles alone, or in combination with the keratotic nodules.

3.7 Data Analysis This is a preliminary survey and most of the data were analyzed using Statistical Package for the Social (SPSS) tool. Appropriate tests of different and multivariate exploratory analysis were carried out.

CHAPTER-IV

RESULTS

4.1 Dermatological Manifestation in Kailali District

Table 4.1 shows the distribution of dermatological manifestations and its prevalence in Kailali district. Among the participants of dermatological examinations, the overall prevalence of arsenicosis is 2.12%. The prevalence is higher in Thapapur VDC (i.e. 2.49%) compared to Sadepani VDC (i.e. 1.11%). Though the prevalence of arsenicosis is apparently higher in female than in male in Mohamadpur VDC, total prevalence in Bardiya district is higher in male than in female. Moreover, in both the sexes, mild cases of arsenicosis predominated in both of the VDCs and none is classifi ed as severe.

Table 4.1: Distribution of Dermatological Manifestations in the Subjects of Kailai District

VDC	Sex	Total Population	No. Examined	Dermatological Manifestation				
				Stage				
				Mild	Moderate	Severe	Total	Prevalence
Thapapur	Male	191	117 (61.26%)	3	1	0	4	3.42
	Female	149	124 (83.22%)	2	0	0	2	1.61
	Subtotal	340	241 (70.88%)	5	1	0	6	2.49
Sadepani	Male	406	298 (73.4%)	7	2	0	9	3.02
	Female	470	359 (76.38%)	4	0	0	4	1.11
	Subtotal	876	657 (75%)	11	2	0	13	1.1
Both	Male	597	396 (66.33%)	10	3	0	13	3.28
	Female	619	502 (81.1%)	6	0	0	6	1.2
	Grand Total	1,216	898 (73.85%)	16	3	0	19	2.12

4.2 Dermatological Manifestation in Bardiya District

Table 4.2 shows the distribution of dermatological manifestations and its prevalence in Bardiya district. Among the participants of dermatological examinations, the overall prevalence of arsenicosis is 2.66%. The prevalence is higher in Mohamadpur VDC (i.e. 3.44%) compared to Jamuni VDC (i.e. 2.35%). Moreover, the prevalence is significantly higher in Female than Male in Mohamadpur VDC, Jamuni VDC and as a whole in both of the VDCs. In both the sexes, mild cases of arsenicosis predominated in both of the VDCs and none is classified as severe.

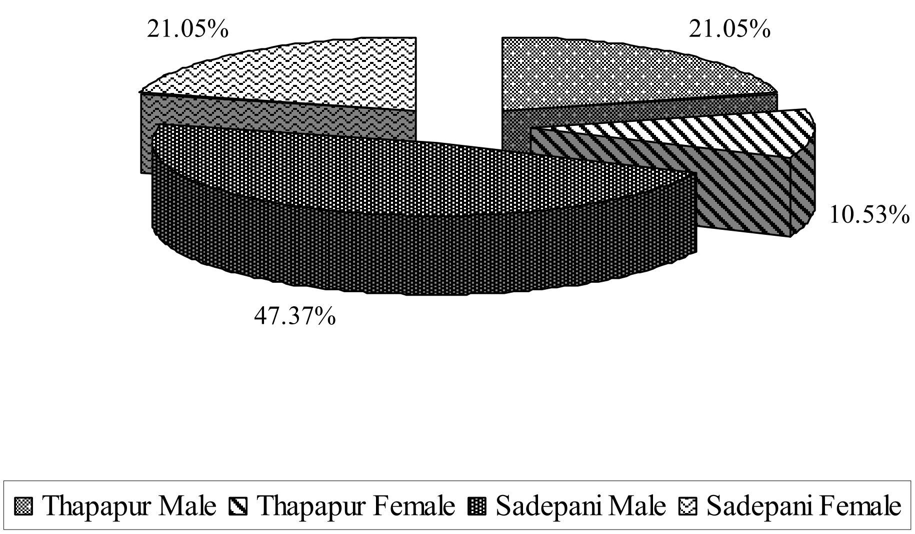
Table 4.2: Distribution of Dermatological Manifestations in the Subjects of Bardiya District

VDC	Sex	Total Population	No. Examined	Dermatological Manifestation				
				Stage				
				Mild	Moderate	Severe	Total	Prevalence
Mohamadpur	Male	70	51 (72.85%)	1	0	0	1	1.96
	Female	78	65 (83.33%)	3	0	0	3	4.61
	Subtotal	148	116 (78.37%)	4	0	0	4	3.44
Jamuni	Male	206	136 (66.01%)	4	1	0	5	3.67
	Female	213	161 (75.58%)	2	0	0	2	1.24
	Subtotal	419	297 (70.9%)	6	1	0	7	2.35
Both	Male	276	187 (67.75%)	5	1	0	6	3.20
	Female	291	226 (77.66%)	5	0	0	5	2.21
	Grand Total	567	413 (72.83%)	10	1	0	11	2.66

4.3 Sexwise Distribution of Arsenicosis Patients in Kailali District

Figure 4.1 shows the sex-wise distribution of arsenicosis patients in Kailali district. 68.42% of the arsenicosis patients are male where as 31.58% are female. Out of the 68.42% of the male patients 21.05% are observed in Thapapur VDC and 47.37% in Sadepani VDC. Similarly, out of the 31.58% of the female patients 10.53% are found in Thapapur VDC and 21.05% in Sadepani VDC. Total number of arsenicosis patients is much higher in Sadepani VDC compared to Thapapur VDC for both of the sexes. However the prevalence of arsenicosis patients is higher in Thapapur VDC than Sadepani VDC

Fig. 4.1 Sexwise Distribution of Arsenicosis Patients in Kalali District

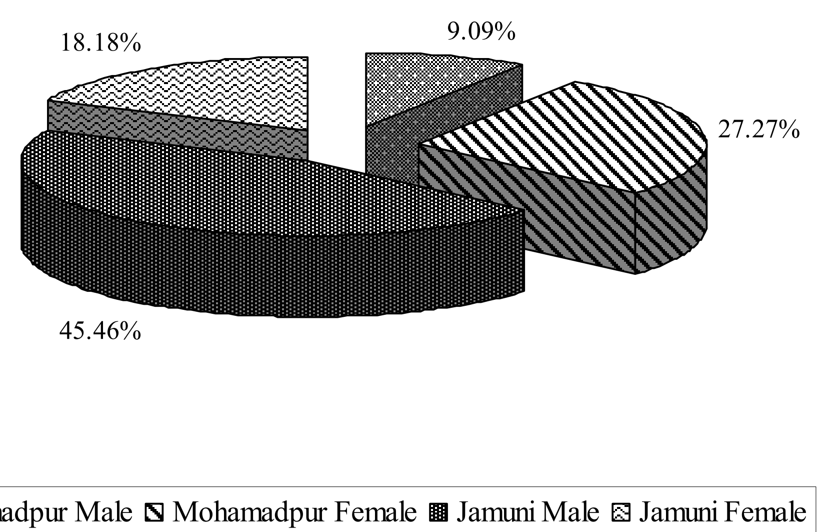


.

4.4 Sexwise Distribution of Arsenicosis Patients in Bardiya District

Figure 4.2 shows the sex-wise distribution of arsenicosis patients in Bardiya district. 54.55% of the arsenicosis patients are male where as 45.45% are female. Out of the 54.55% of the male patients 9.09% are observed in Mohamadpur VDC and 45.46% in Jamuni VDC. Similarly, out of the 45.45% of the female patients 27.27% are found in Mohamadpur VDC and 18.18% in Jamuni VDC. Total number of arsenicosis patients is much higher in Jamuni VDC compared to Mohamadpur VDC for both of the sexes. However the prevalence of arsenicosis patients is higher in Mohamadpur VDC than Jamuni VDC. This is because number of examined population is less in Mohamadpur VDC than in Jamuni VDC.

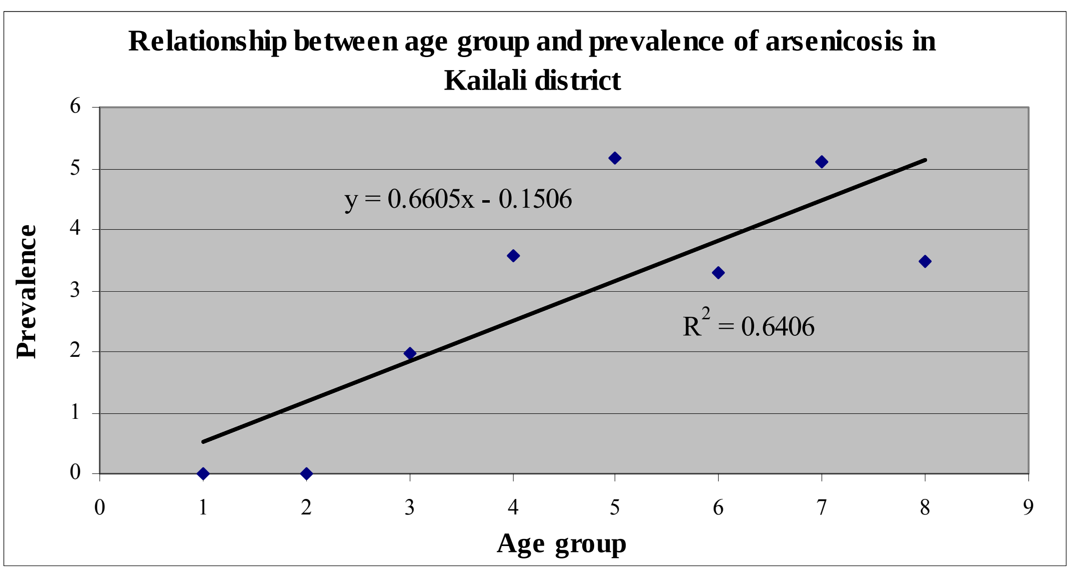
Fig. 4.2 Sexwise Distribution of Arsenicosis Patients in Bardiya District



4.5 Relationship Between age group and prevalence of arsenicosis in Kailali District

Figure 4.3 shows the relation between the age of the people consuming arsenic contaminated water and the prevalence of the arsenicosis. The coefficient of determination (R^2) between the age group and prevalence of arsenicosis is found to be 0.6406. This shows that 64% of the number of arsenicosis patient in Kailali district is explained by age of the people. The higher the age of the people consuming arsenic contaminated water the higher is the prevalence of arsenicosis. Also t- test has been performed for the test of significance of correlation between the data's under the null hypothesis that "the data's are not correlated in the population." The value of test statistic "t" calculated for 6 degrees of freedom is 3.27. The tabulated value of test statistic "t" at 0.05 level of significance for 6 degrees of freedom is 2.45, which is less than the calculated value (3.27). Hence from the theory of test of significance null hypothesis is rejected. This means that the sample correlation is significant of correlation in the population or data's are significantly correlated.

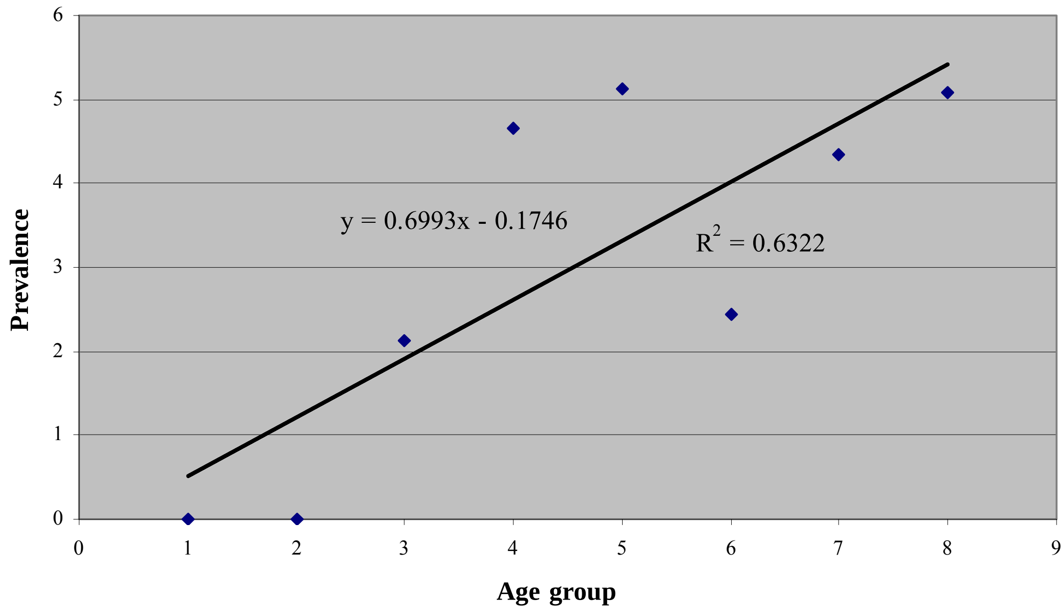
Fig. 4.3 Relationship between age group and prevalence of arsenicosis in Kailali District



4.6 Relationship Between age group and prevalence of arsenicosis in Bardiya District

Figure 4.4 shows the relation between the age of the people consuming arsenic contaminated water and the prevalence of the arsenicosis. The value of R^2 between the age group and prevalence of arsenicosis is found to be 0.6322. This shows that 63% of the number of arsenicosis patient in Bardiya district is explained by age of the people. The higher the age of the people consuming arsenic contaminated water the higher is the prevalence of arsenicosis. Also t- test has been performed for the test of significance of correlation between the data's under the null hypothesis that "the data's are not correlated in the population." The value of test statistic “t” calculated for 6 degrees of freedom is 3.21. The tabulated value of test statistic “t” at 0.05 level of significance for 6 degrees of freedom is 2.45, which is less than the calculated value (3.21). Hence from the theory of test of significance null hypothesis is rejected. This means that the sample correlation is significant of correlation in the population or data's are significantly correlated.

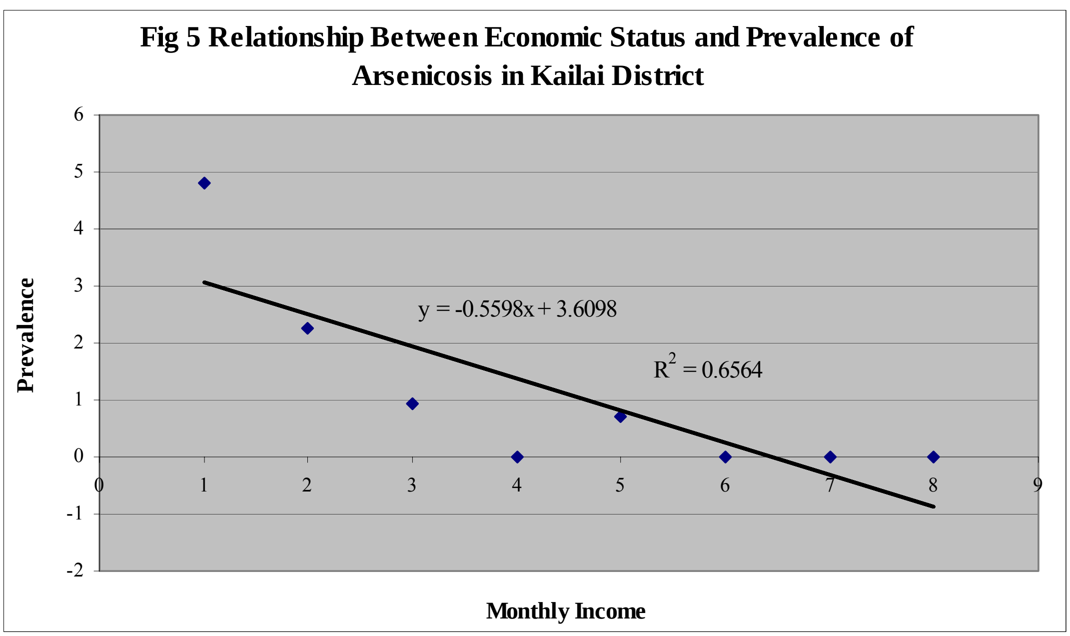
Fig. 4.4 Relationship between age group and prevalence of arsenicosis in Bardiya district



4.7 Relationship between Economic Status and Prevalence of Arsenicosis in Kailali District

Figure 4.5 shows the relation between the economic status of the people consuming arsenic contaminated water and the prevalence of the arsenicosis. The value of R^2 between the economic status and prevalence of arsenicosis is found to be 0.6564. This shows that 65% of the number of arsenicosis patient in Kailali district is explained by economic status of the people. The lower the economic status of the people consuming arsenic contaminated water the higher is the prevalence of arsenicosis. Also t- test has been performed for the test of significance of co-relation between the data's under the null hypothesis that "the data's are not correlated in the population." The value of test statistic "t" calculated for 6 degrees of freedom is 3.38. The tabulated value of test statistic "t" at 0.05 level of significance for 6 degrees of freedom is 2.45, which is less than the calculated value (3.38). Hence from the theory of test of significance null hypothesis is rejected. This means that the sample correlation is significant of correlation in the population or data's are significantly correlated.

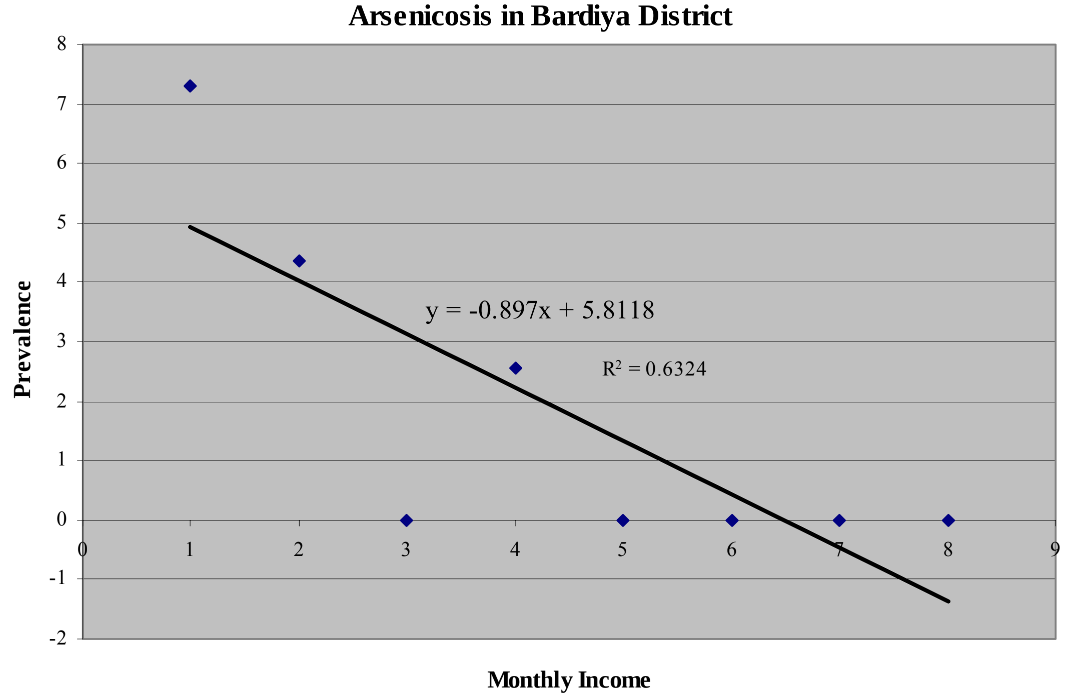
Fig. 4.5 Relationship between Economic Status and Prevalence of Arsenicosis in Kailali District



4.8 Relationship between Economic Status and Prevalence of Arsenicosis in Bardiya District

Figure 4.6 shows the relation between the economic status of the people consuming arsenic contaminated water and the prevalence of the arsenicosis. The value of R^2 between the economic status and prevalence of arsenicosis is found to be 0.6324. This shows that 63% of the number of arsenicosis patient in Bardiya district is explained by economic status of the people. The lower the economic status of the people consuming arsenic contaminated water the higher is the prevalence of arsenicosis. Also t- test has been performed for the test of significance of correlation between the data's under the null hypothesis that "the data's are not correlated in the population." The value of test statistic "t" calculated for 6 degrees of freedom is 3.212. The tabulated value of test statistic "t" at 0.05 level of significance for 6 degrees of freedom is 2.45, which is less than the calculated value (3.21). Hence from the theory of test of significance null hypothesis is rejected. This means that the sample correlation is significant of correlation in the population or data's are significantly correlated.

Fig. 4.6 Relationship Between Economic Status and Prevalence of Arsenicosis in Bardiya District



4. 9 Population at risk

Considering the interim guideline adopted by Nepal (50ppb) as safe, the population consuming water above this value was considered a population at risk. The total number of population was 53,594 and population at risk was 4,783 which constitute the 8.92% of the total population in the four VDCs of Kailali and Bardiya districts. Number of risk population in two VDCs of Kailali district was 4,216 i.e. 13.37% of total population where as it was 567 i.e. 2.56% of total population in two VDCs of Bardiya district. This figure clearly shows that number of population at risk in Kailai district is much higher than in Bardiya district. Out of 13.37% population at risk in Kailali district, Thapapur VDC has 1,292 i.e. 9.52% of total population and Sadepani VDC has 2,924 i.e. 16.28% of total population. Similarly, Out of 2.56% population at risk in Bardiya district, Mohamadpur VDC has 148 i.e. 1.4% of total population and Jamuni VDC has 419 i.e. 3.62% of total population. Population at risk of the individual study area is presented in table 4.3.

Table 4.3: Population at risk

Name of the VDC	Total Population	Population at Risk (>50ppb)
Kailali District		
Thapapur	13,559	1,292 (9.52%)
Sadepani	17,956	2,924 (16.28%)
Sub-Total	31,515	4,216 (13.37%)
Bardiya District		
Mohamadpur	10,521	148 (1.40%)
Jamuni	11,558	419 (3.62%)
Sub-Total	22,079	567 (2.56%)
Grand Total	53,594	4,783 (8.92%)

4.10 Socioeconomic Status of Risk Household

Considering the People who have completed at least primary education as a literate and others illiterate, 50.57% of the total population from risk household is illiterate and remaining 49.43% are literate. Out of 49.43% literate, 21.28% have completed primary education, another 21.5% have completed secondary education and only 6.63% joined higher education. The rate of illiteracy was 49.51% in Bardiya District where as it was 57.04% for Kailali District. Highest value of illiteracy was found to be 65.98% in the risk population of Thapapur VDC of Kailali District where as it was least i.e. 40.40% in Jamuni VDC of Bardiya District. Detailed percentage of none, primary, secondary and higher education is shown in table 6.

Taking the population having monthly income less than NRs 1000 as poor, 1000-4000 as fair, 4000-7000 as good and more than 7000 as very good; 27.99% of total population from risk household have poor, 38% have fair, 28% have good, and remaining 5.94% have very good economic condition. If we overview individual district, the economic status of Bardiya is higher than that of Kailali. Similarly, the economic status of Jamuni VDC of Bardiya district is much higher than the other three VDC with 15.15% of population under very good category and 31% of population under good category. VDC with least economic status was found to be Thapapur of Kailali district in which 36.1% of the population is under poor category and 38% under fair category. Only 2.9% of total risk population falls in very good category in thapapur VDC. Detail overview of monthly income in different VDCs is shown in table 4.4.

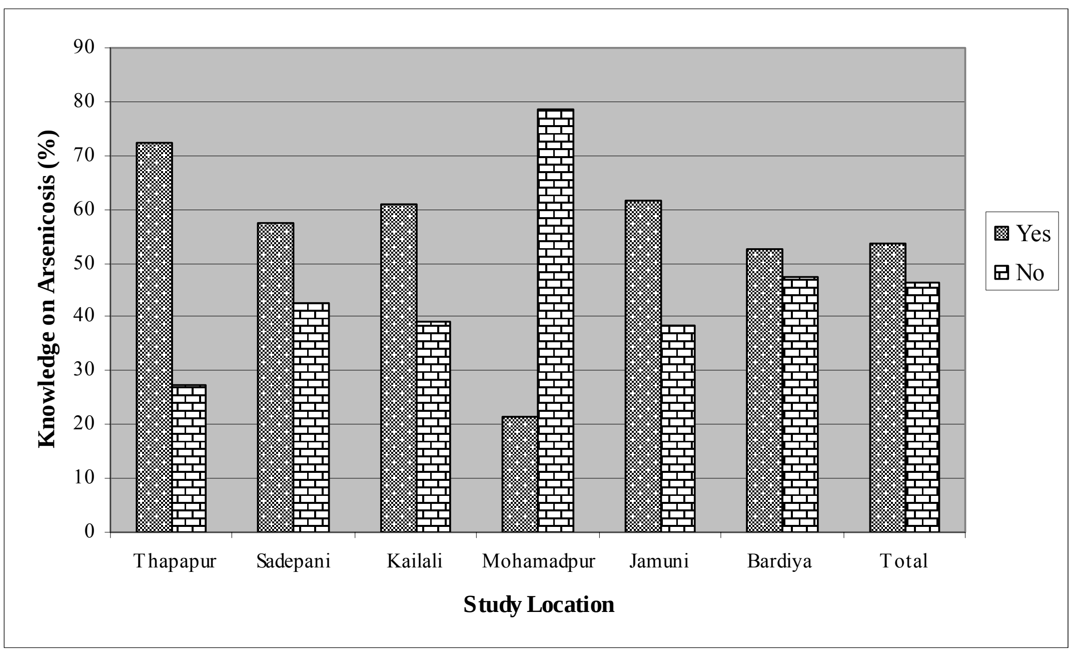
Table 4.4: Education and Average Monthly Income of Risk Household

Education	VDCs				
	Thapapur	Sadepani	Mohamadpur	Jamuni	Total
None	159 (65.98%)	316 (48.1%)	68 (58.62%)	120 (40.4%)	663 (50.57%)
Primary	55 (22.82%)	142 (21.61%)	28 (24.14%)	54 (18.18%)	279 (21.28%)
Secondary	20 (8.3%)	171 (26.03%)	17 (14.66%)	74 (24.92%)	282 (21.51%)
Higher education	7 (2.90%)	28 (4.26%)	3 (2.59%)	49 (16.5%)	87 (6.63%)
Total	241 (100%)	657 (100%)	116 (100%)	297 (100%)	1,311 (100%)
Monthly average Income (NRs)					
1000 or less	87 (36.1%)	184 (28.0%)	23 (19.82%)	73(24.57%)	367 (27.99%)
1000-2000	49 (20.33%)	127 (19.33%)	21 (18.10%)	48 (16.16%)	245 (18.68%)
2000 -3000	28 (11.61%)	79 (12.02%)	10 (8.62%)	17 (5.72%)	134 (10.22%)
3000-4000	15 (6.22%)	61 (9.28%)	17 (14.65%)	22 (7.40%)	115 (8.77%)
4000-5000	27 (11.20%)	112 (17.04%)	19 (16.37%)	15 (5.05%)	173 (13.19%)
5000-6000	17 (7.05%)	43 (6.54%)	11 (9.48%)	30 (10.10%)	101 (7.70%)
6000-7000	11 (4.56%)	32 (4.87%)	8 (6.89%)	47 (15.82%)	98 (7.47%)
7000 or above	7 (2.90%)	19 (2.89%)	7 (6.03%)	45 (15.15%)	78 (5.94%)
Total	241 (100%)	657 (100%)	116 (100%)	297 (100%)	1,311 (100%)

4.11 Knowledge of Respondents on Arsenicosis

Fig 4.7 showed that 53.59% i.e. 127 out of 237 respondents from all of the VDCs under study are known about Arsenicosis. Knowledge on health impact of Arsenic contamination was higher in Kailai district compared to Bardiya district. 60.80% i.e. 95 out of 176 of the total respondents are known about Arsenicosis in Kailali district while the value reduced to 52.45% i.e. 32 out of 61 in Bardiya district. Comparing the percentage of respondents who answered that they have knowledge on Arsenicosis, Thapapur VDC of Kailai district has highest percentage i.e. 72.5% (29 out of 40) where as Mohamadpur VDC of Bardiya district has least percentage i.e. 21.42% (3 out of 14).

Fig. 4.7 Comparative Knowledge of Respondents on Arsenicosis



CHAPTER - V

DISCUSSION

The results of this study clearly show that arsenic in drinking water is a serious public health problem in lowland Nepal, known as Terai, where almost half (12 million) of the Nepalese population resides. Although contamination of tube well water by arsenic in this area was first reported in 1999, only sporadic information on the situation has been published. Among such studies, it was reported that 29% of more than 20,000 tube wells had arsenic concentrations exceeding the WHO standard (10 μg/l) (RWSSSP, 2003) and approximately 0.5 million people in Terai were at risk of consuming water with an arsenic concentration >50 μg/L (Shrestha *et.al.*, 2003). However, low sampling rates and/or selection biases (e.g., excluding those consuming uncontaminated water) in these surveys may have obscured the real situation. Total population at risk in the selected wards of Kailali and Bardiya Districts together was 4,783 (i.e. 8.92% of total population) where as it was 4,216 (i.e. 13.37% of total population) in Kailali district and 567 (i.e. 2.56% of total population) in Bardiya district (Table 4). Higher percentage of tubewell contamination in this region might be due to geological and hydrological condition of the area. The Kailai district is located at the bank of Karnali River following from higher Himalaya through the Siwalik and the Bardiya district lies on the bank of Karnali and Veri River and hence the ground is highly affected by the historical sedimentation of arsenic laden soils. Moreover, both of the districts have agriculture as a major profession and hence use of chemical fertilizer and pesticides is excessive.

This study showed a much higher proportion of contaminated tube wells and of prevalence of AASL than in previous reports (Shrestha *et.al,* 2003; RWSSSP, 2003 and DWSS, 2002). This indicated the existence of a “hot spot” in lowland Nepal, where few tube wells provide the inhabitants with safe water. The prevalence rate in this area was comparable to those reported for Bangladeshi communities, in which the diagnosis was made by the same personnel using the same criteria, (Ahmad *et.al.,* 1999 and Ahamad *et.al.,* 1997), where the existence of severe arsenic-contamination has been well recognized. The result of present study showed sex, age, and socioeconomic differentials in exposure and skin lesions.

5.1 Impact of gender on prevalence of arsenicosis

Among the participants of dermatologic examinations, the overall prevalence of arsenicosis was 2.12% in Kailali district and 2.66% in Bardiya district which is consistent to the result that prevalence of arsenicosis in lowland Terai of Nepal varied between 1.3% and 5.1% (DWSS, 2002). The prevalence is apparently higher in males than in females except in the Mohamadpur VDC where prevalence is higher in female and a virtually negligible prevalence among those less than 15 years old. In both sexes, mild cases of arsenicosis predominated and none was classified as severe (Table 1 and Table 2). Moreover percentage of male patient is much higher compared to the female patients in all of the VDCs under study with higher percentage in Kailali compared to Bardiya (Fig 1 and Fig 2).

The higher susceptibility of males to AASL was consistent with the results of other studies (Watanabe *et.al.,* 2004; Guha Mazumder *et.al.,* 1998 and Rahman, 2006). A few previous reports have indicated that men are more affected by AASL, including skin cancer, than women (Chen et al. 2003; Ferreccio et al. 2000; Guha Mazumder et al. 1998; Kadono et al. 2002; Tseng 1977; Watanabe et al. 2001). In contrary, other studies found women to be more susceptible than men (Ahmad et al. 1999) or did not identify any difference (Ahsan et al. 2000; Hadi and Parveen 2004; Tondel et al. 1999).

Sex related difference in susceptibility might have biologic origin, e.g., difference in the metabolism of arsenic, and is worthy of further study. An involvement of hormone interactions is possible, because Arsenic has been shown to interact with estrogen (Kitchin and Wallace 2005; Waalkes et al. 2004), which affects all the cell types of importance for skin physiology (e.g., epidermal keratinocytes, dermal fibroblasts, melanocytes) (Thornton 2005). In addition, differences between the sexes in the metabolism of Arsenic might have influenced the likelihood of developing skin lesions. Compared with females, males often have a higher fraction of the monomethylated Arsenic metabolite monomethylarsonate in urine (Hopenhayn-Rich et al. 1996; Vahter et al. 2002), which has been associated with increased risk of AASL, including skin cancer (Chen et al. 2003; Del Razo et al. 1997).

Lifestyle differences such as smoking and alcohol use also affect arsenic speciation and total urinary arsenic (Hopenhayn-Rich et al. 1996; Kurttio et al. 1998). Trace amounts of arsenic are found in tobacco. Studies of cigarettes manufactured in the US estimate arsenic concentrations per cigarette at 10.7 ng (range 1.6-24.9) (IARC, 2004). Use of tobacco and alcohol was more common on male rather than female in the study area (table not shown) and hence it might have been the reason for the higher prevalence of arsenicosis found. Both Arsenic and smoking are potent inducers of oxidative stress (An et al. 2004; Helmersson et al. 2005; Nishigori et al. 2004; Pi et al. 2003), and a recent small-scale study suggested that genetic susceptibility to oxidative stress, as determined by polymorphisms in the myeloperoxidase and catalase genes, is associated with elevated risk of developing Arsenic-related hyperkeratosis (Ahsan et al. 2003). Also, AASL in Inner Mongolia were shown to be related to markers of oxidative Deoxyribonucleic acid (DNA) damage (Fujino et al. 2005).

Other susceptibility factors possibly involved in the observed differences in AASL between males and females include water intake and sun exposure. The higher risk of AASL in men than in women has been hypothesized to be caused by a higher intake of water (and thereby high Arsenic intake) because of higher physical activity. Male of the study area started to use tubewell water earlier in life than women as some women moved into study area from other areas for marriage. Similarly, male of the study area are more exposed to the sun than women, where agriculture is the most common occupations among men, and women are mainly occupied in domestic work. Moreover, male generally puts off their outer clothes while working in the field. This may imply an increased risk of toxic effects in the skin. A research in interactions between Arsenic and ultraviolet (UV) irradiation has demonstrated that oxidative cell damage and cocarcinogenicity has increased in mouse skin (Uddin et al. 2005). Possibly, Arsenic-induced resistance to apoptosis in the skin may allow UV-damaged cells to escape normal cell population control (Pi et al. 2005). However, the role of sunlight is not all that obvious, because women had a prevalence of pigmentation changes similar to that of men (Rahman et al. 2006). Also, hyperkeratosis, which was more frequent among men, was not present on the most sun-exposed parts of the body, but rather on the palms of the hands and soles of the feet.

5.2 Impact of Socio-economic status on prevalence of arsenicosis

An important finding of the present study was that deficiency in some nutritional factors may increase the risk of AASL. The majority of our patients have come from very poor socioeconomic class with about 95% unable to eat animal protein (meat / fish) everyday (table 6). In this study individuals with poor nutritional status are more susceptible to develop arsenic toxicity. Statistical analysis of the observed data showed that 65% of the number of arsenicosis patient in Kailali district (Fig 3) and 63% patients in Bardiya district (Fig 4) are explained by economic status of the people. The lower the economic status of the people consuming arsenic contaminated water the higher is the prevalence of arsenicosis. Also, from the theory of test of significance it is clear that the sample correlation is significant of correlation in the population or data's are significantly correlated.

The major reason behind the impact of SES on prevalence of arsenicosis is that people from higher socioeconomic groups have taken the lead in getting arsenic free or less arsenic water by installing newer tubewells in arsenic free zone, by increasing the depth of tubewell or by using arsenic filters especially in Thapapur VDC of Kailali district. On the other hand, people from poor socio-economic group are being compelled to use available option of water whether it is arsenic free or not. Greater arsenic concentrations in wells used by those at lower income may occur due to differing well depths. Wealthier people are more likely to have deeper wells, which tend to cost more and have lower arsenic concentrations.

Moreover, people from higher socioeconomic group posses higher intake of nutritional diet. Low protein and amino acid diets increase risks of arsenic-related health effects, and some studies in humans have found worsened arsenic associated health effects among those consuming lower amounts of meat, eggs, and vegetables (Chen et al. 1988; Hoffman et al. 1992; Lammon and Hood 2004; Maiti and Chatterjee 2001; Mitra et al. 2004; Vahter and Marafante 1987; Yang and Blackwell 1961). Greater intakes of protein and amino acids resulted in increased urinary excretion of arsenic. Those whose protein consumption exceeded 1.87 g/kg/day had higher urinary arsenic, even after controlling for arsenic intake through drinking water (Tseng 1977; Hsueh et al. 1995), Chile (Borgono et al. 1977; Zaldivar and Guillier 1977) and West Bengal in India (Mazumder et al. 1998). Contrary to these findings, a study from Atacamen˜ o in northern Chile reported no evidence of malnutrition among individuals with AASL (Smith et al. 2000). Vitamin 'A' plays an important role in differentiation of various tissues, especially skin lesion and deficiency of this vitamin increases the susceptibility. Vitamin 'C' and methionine have been found to reduce the toxicity of arsenic (Hsueh et al. 1995, 1998). Furthermore retinoids or vitamin 'A' is associated with clinical regression of the disease; while vitamin 'E' has been found to potentiate the protective effect of vitamin 'A' against the toxicity.

Poor nutritional status of the patients may increase arsenic retention in the body and thus lead to severity of clinical complications. Patients with protein-energy malnutrition have inadequate supply of methionine from dietary sources, and studies in rabbits have shown low amount of methionine or protein in the diet decreased methylation of inorganic arsenic (Vahter et. al, 1987); and deficiency of other dietary trace elements including zinc and selenium (Engel and Receveur, 1993) may lead to arsenic accumulation and contribute to the toxic effects in the body. A recent study has shown that low intake of calcium, animal protein, folate and dietary fiber may increase susceptibility to AASL (Mitra et. al, 2004). Low intake of animal protein, calcium, fiber, folate, and vitamin 'C' has potential effects on arsenicosis. It is not clear why animal protein should be important with regard to skin lesions. Fiber intake also lacks explanation. It is possible that fiber might reduce arsenic absorption from the gastrointestinal tract, but we know of no evidence for this (Soma et. al, 2004). A large fraction of fiber intake in risk population of this study comes from rice intake, but because rice is the main source of carbohydrate for these people, and carbohydrate intake did not differ between cases and controls, reduced risks cannot be attributed to rice intake.

In the present study we found that prevalence of arsenicosis was apparently related to the educational status of the risk population (Table 6). The lower the literacy rate the higher was the prevalence of arsenicosis in all of the VDCs under study. Moreover knowledge of respondents on arsenicosis was fairly low in the study area (Fig.7). Our results revealed that relatively educated people (indicated by table 6) have relatively higher knowledge on arsenic contamination in drinking water and its health impact and hence are at lower risk of drinking arsenic contaminated water compared with illiterate people. It is expected that socio-economically wealthy people are better educated and more health conscious than poor people. These arguments are consistent with the findings of Hadi (2003).

The greatest weakness of the present study was that nutrition habit of the risk population was not observed directly and we assumed that participants with higher monthly income would have taken more nutritional diet.

5.3 Impact of age on prevalence of arsenicosis

The most convenient finding of the present study was that increased age may increase the risk of AASL. The majority of our patients have come from higher age group i.e. more than 40 years (table not shown). Similar findings were indicated from China (Guo et. al., 2006). Statistical analysis of the observed data showed that 64% of the number of arsenicosis patient in Kailali district (Fig 5) and 63% patients in Bardiya district (Fig 5) are explained by age of the people. The higher the age of the people consuming arsenic contaminated water the higher is the prevalence of arsenicosis. Also, from the theory of test of significance it is clear that the sample correlation is significant of correlation in the population or data's are significantly correlated.

In this study, the highest prevalence of skin lesions was found among individuals from >40 years of age, with a peak at >60 years. On average, those people had been using tubewell water for about 15 years. Younger age groups had lower prevalence values. As children often are particularly susceptible to chemical toxicity (WHO, 2002), the poisoning of arsenic toxicity was found to be more on individuals from higher age group. This might due to the longer duration of consumption and higher amount of consumption per day by older people than children. Moreover, older people reside always in their home and use more water and consequently more arsenic. Age is known to influence arsenic metabolism, with urinary arsenic concentrations peaking at younger ages, due to poorer methylation among older people (Hsueh et al. 1998; Kurttio et al. 1998). Nutrient intake is associated with changes in urinary arsenic metabolites, with greater intake of cysteine associated with increased excretion of dimethylarsinous acid (Heck et al. 2007). There is interindividual variation in arsenic excretion, which may be modified by host factors such as age and physical activity level (Vahter et al. 2006). Folate deficiency has been associated with impaired arsenic methylation and folic acid supplementation has improved methylation (Gamble et al. 2006). Age is also related to protein intake, with adults typically consuming less protein as they age (Smit et al. 1999). If protein sources are scarce, protein may be given to honored family members or those undertaking the greatest physical labor.

This study, therefore, suggests that there is an urgent necessity for reinforced arsenic mitigation activities in lowland Terai Nepal. The problem must be tackled in an integrated, comprehensive approach to minimize the risk to the affected population. Prudent public health decisions should not wait. Thus, early implementation of mitigation measures to provide arsenic-free water and community awareness programs are needed.

CHAPTER – VI

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

The result of present study showed sex, age, and socioeconomic differentials in exposure and skin lesions. From the thoroughly evaluation of the result we have drawn the following conclusions:

- The findings of this study reinforce the gravity of arsenic problem in Kailali and Bardiya district of western Terai Nepal with The overall prevalence of arsenicosis as 2.12% in Kailali district and 2.66% in Bardiya district.

- Gender has apparent effect on the prevalence of arsenicosis. Prevalence of acute symptoms is much higher among males than in females and a virtually negligible prevalence among those less than 15 years old.

- The people from older age group are affected significantly to a far greater extent than people from younger age group i.e. there is direct relationship between age and prevalence of arsenicosis.

- The people from poor socioeconomic group are affected significantly to a far greater extent than people from non-poor socioeconomic group i.e. there is inverse relationship between SES and prevalence of arsenicosis.

- Since major causes of arsenicosis problem are poverty, illiteracy and lack of mitigating and monitoring measures, arsenic mitigation programmes should target the arsenic exposed malnourished poor population as a priority.

6.2 Recommendations

Various case management practices are being adopted by the government and private sector organizations for the minimization of arsenicosis problem. However, such efforts could be fruitful if the recommended actions are put into practice.

- A collective knowledge base on what safe water is, and alternative ways to get it has to be developed for sustainability at the community level. Messages should promote widespread understanding, not fear. Knowledge should not be restricted to influential individuals, committee members, or literate people.

- More information, both quantitative and qualitative, is needed on the general relationship between arsenicosis risk and dietary habits and general nutrition in order to understand why low SES is so strongly associated with high risk of arsenicosis.

- It will be useful to know have more information about gender differences in arsenicosis prevalence rates as compared to 'prevalence odds risks' among poor, middle class, and rich people affected by arsenicosis separately.

- In 'hot spots', where there are many people affected by arsenic-related illness, it is essential to provide as much health care and information as soon as possible. As many such severely affected populations are poor and illiterate, information and help needs to be provided in a way that people can understand and make use of it.

- In general it is recommended that every effort be made to promote self-help, self-confident approach to the arsenic problem and safe drinking water in the community. This problem is so vast, that it can only be solved with the full and active participation of all, whatever their position in the social or administrative hierarchy.

REFERENCE

- Adhikari, S.P., 2005. Arsenic Contamination in Groundwater and its Health impacts in Balchanpur Area Rautahat Distrcit, Nepal. Dissertation submitted to TU, Central Department of Environmental Science
- ATSDR, 1998. Draft Toxicological Profile for Arsenic. Prepared for the U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Research Triangle Institute
- Ahmad, S.A, Bandaranayake D, Khan AW, Hadi SA, Uddin G, Halim A, 1997. Arsenic contamination in ground water and arsenicosis in Bangladesh. International Journal Environ Health Res 7: 271–276
- Ahmad, S.A, Maharjan M, Watanabe C, Ohtsuka, 2004. Arsenicosis in two villages in Terai, lowland Nepal. Environ Science 11(3): 179-88
- Ahmad, S.A, Sayed M.H.S.U, Hadi S.A, Faruquee M.H, Khan M.H, Jalil M.A, Ahmed R, Khan W.A, 1999. Arsenicosis in a village in Bangladesh. Int J Environ Health Res 9: 187–195
- Ahsan, H, Chen Y, Wang Q, Slavkovich V, Graziano JH, Santella RM, 2003. DNA repair gene XPD and susceptibility to arsenic-induced hyperkeratosis. Toxicol Lett 143(2):123–131
- Ahsan, H, Perrin, M, Rahman, A, Parvez, F, Stute M, Zheng, Y, Milton, A. H, Brandt-Rauf, P, van Geen, A, Graziano, J., 2000. Associations between drinking water and urinary arsenic levels and skin lesions in Bangladesh. J Occup Environ Med, 42(12): 1, 195-201
- An, Y, Gao Z, Wang Z, Yang S, Liang J, Feng Y, 2004. Immunohistochemical analysis of oxidative DNA damage in arsenic-related human skin samples from arsenic-contaminated area of China. Cancer Lett 214(1):11–18
- Borgono, J.M., Vicent P, Venturino H, Infante A., 1977. Arsenic in the drinking water of the city of Antofagasta: epidemiological and clinical study before and after the installation of a treatment plant. Environ Health Perspect 19:103–05.

- Buchet, J.P., Lauwerys R, Roels H., 1981. Comparison of the urinary excretion of arsenic metabolites after a single oral dose of sodium arsenite, monomethylarsonate, or dimethylarsinate in man. Int Arch Occup Environ Health. 48(1):71–79
- Cebrian, M., Martinez, G., X Chamorro, V.; Jauge, P., 1983. Urinary uroporphyrin as an indicator of arsenic exposure in rats. Proc. West. Pharmacol. Soc. 26, 171-174
- CBS,. 2001. Statistical pocket book. Central Bureau of Statistics Nepal, HMG/National Planning Secretariat.
- Chang, T.C., Hong, M.C., Chen, C.J., 1991. Higher prevalence of goiter in endemic area of blackfoot disease of Taiwan. Chinese J Formos Med Assoc; 90(10): 941-6
- Chen, Y.C., Guo, Y.L., Su, H.J., Hsueh, Y.M., Smith, T.J., Ryan, L.M., 2003. Arsenic methylation and skin cancer risk in southwestern Taiwan. J Occup Environ Med. 45(3):241–248
- Chen, C.J., Wu, M.M., Lee, S.S., Wang, J.D., Cheng, S.H. and Wu, H.Y., 1988. Atherogenicity and carcinogenicity of high-arsenic artesian well water. Multiple risk factors and related malignant neoplasms of blackfoot disease. Arteriosclerosis 8(5), 452 – 60
- Cullen, W.R., and K.J. Reimer., 1989. Arsenic speciation in the environment. Chem. Rev 89: 713-764
- Del Razo, L.M., Garcia-Vargas, G.G., Vargas, H., Albores, A., Gonsebatt, M.E., Montero, R., 1997. Altered profile of urinary arsenic metabolites in adults with chronic arsenicism. A pilot study. Arch Toxicol 71(4):211–217
- DWSS, and UNCF, 2002. A Study on Health Effects of Arsenic Contaminated Drinking Water in Nawalparasi District, Nepal. Department of Water Supply and Sanitation/United Nations Children's Fund Kathmandu, Nepal: Environment and Public Health Organization
- Engel, R.R., and Receveur, O., 1993. Arsenic ingestion and internal cancers: a review [letter]. *Am. J. Epidemiol. 138*, 896-897
-

- EPA., 2000. Arsenic Occurrence in Public Drinking Water Supplies. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-815-R-00-023
- Erica, Weir., 2002. Arsenic and drinking water. CMAJ 166(1): 69
- Feinglass, E.J., 1973. Arsenic intoxication from well water in the United States. N Engl J Med 288:828-830.
- Fennell, J.S. and Stacy, W.K., 1981. Electrocardiographic changes in acute arsenic poisoning. Ir. J. Med. Sci., 150: 338
- Ferreccio, C., Gonzalez, C., Milosavjlevic, V., Marshall, G., Sancha, A.M., Smith, A.H., 2000. Lung cancer and arsenic concentrations in drinking water in Chile. Epidemiology. 11(6):673–679
- Fujino, Y., Guo, X., Liu, J., Matthews, I.P., Shirane, K., Wu, K., 2005. Chronic arsenic exposure and urinary 8-hydroxy-2′-deoxyguanosine in an arsenic-affected area in Inner Mongolia, China. J Expo Anal Environ Epidemiol. 15(2):147–152
- Gamble, M.V., Liu, X., Ahsan, H., Pilsner, J.R., Ilievski, V., Slavkovich, V., 2006. Folate and arsenic metabolism: a double-blind, placebo-controlled folic acid-supplementation trial in Bangladesh. Am J Clin Nutr 84(5):1093-1101
- Guha Mazumder, D.N., Haque, R., Ghosh, N., 1998. Arsenic levels in drinking water and the prevalence of skin lesions in West Bengal, India. Int J Epidemiol 27:871–7
- Guha Mazumder, D.N., 2003. Criteria for case definition of arsenicosis. In: Chappell WR, Calderon RL, Thomas DJ, eds. Arsenic exposure and health effects V. Amsterdam: Elsevier. 117–33
- Hadi, A. and Parveen, R., 2004. Arsenicosis in Bangladesh: prevalence and socioeconomic correlates. Public Health. 118:559–64
- Hassan, M.M., Atkins, P.J., Dunn, C.E., 2005. Social implications of arsenic poisoning in Bangladesh. Soc Sci Med
- Heck, J.E., Gamble, M.V., Chen, Y., Graziano, J.H., Slavkovich, V., Parvez, F., 2007. Consumption of folate-related nutrients and metabolism of arsenic in Bangladesh. Am J Clin Nutr. 85(5):1367-1374

- Helmersson, J., Larsson, A., Vessby, B., Basu, S., 2005. Active smoking and a history of smoking are associated with enhanced prostaglandin $F_{2\alpha}$, interleukin-6 and F_2-isoprostane formation in elderly men. Atherosclerosis. 181(1):201–207
- Hindmarsh, J.T., Szuler, I.M., Williams, C.N., Park-Dinesoy, H., 1979. Massive variceal hemorrhage secondary to presinusoidal portal hypertension due to arsenic poisoning. Can.Med. Assoc. J. 120:168-171
- Hoffman, D.J., Sanderson, C.J., LeCaptain, L.J., Cromartie, E., Pendleton, G.W., 1992. Interactive effects of arsenate, selenium, and dietary protein on survival, growth, and physiology in mallard ducklings. Arch Environ Contam Toxicol 22(1):55-62
- Hopenhayn-Rich, C., Biggs, M.L., Smith, A.H., Kalman, D.A., Moore, L.E., 1996. Methylation study of a population environmentally exposed to arsenic in drinking water. Environ Health Perspect. 104:620–628
- Hsueh, Y.M., Cheng, G.S., Wu, M.M., Kuo, T.L., Chen, C.J., 1995. multiple risk factors associated with arsenic-induced skin cancer: E.ects of chronic liver diseases and malnutritional status. Br. J.Cancer 71, 109 – 14
- Hsueh, Y.M., Huang, Y.L., Huang, C.C., Wu, W.L., Chen, H.M., Yang, M.H., Lue, L.C., Chen, C.J., 1998. Urinary levels of inorganic and organic arsenic metabolites among residents in an arseniasis-hyperendemic area in Taiwan. J. Toxicol. Environ. Health 54(6), 431 – 44.
- Huang, Y.C., Chen, W., Evans, M.A., Mitchell, M.E., Shultz, T.D.. 1998. Vitamin B-6 requirement and status assessment of young women fed a high-protein diet with various levels of vitamin B-6. Am J Clin Nutr 67(2):208-220
- IARC., 2004. Some Drinking-Water Disinfectants and Contaminants, Including Arsenic. International Agency for Research on Cancer Monogr Eval Carcinog Risks Hum 84.
- IPCS., 2001. Summary In: IPCS editor. Environmental Health Criteria 224: Arsenic and Arsenic Compounds. Second ed. Geneva: World Health Organization

- Jordan, D.M., McClelland, A., Kendig, R, Frans., 1997. Monosodium methanearsonate influence on broadleaf weed control with selected postemergence-directed cotton herbicides. J. Cotton Sci. 1: 72-75
- Kadono, T., Inaoka, T., Murayama, N., Ushijima, K., Nagano, M., Nakamura, S., 2002. Skin manifestations of arsenicosis in two villages in Bangladesh. Int J Dermatol. 41(12):841–846
- Kanel., S.R., H. Choi, K.W., Kim, S.H., 2004. Arsenic contamination in groundwater in Nepal: A New Perspective. And More Health Threat In South Asia Region
- Kitchin, K.T., and. Wallace, K., 2005. Arsenite binding to synthetic peptides based on the Zn finger region and the estrogen binding region of the human estrogen receptor-alpha. Toxicol Appl Pharmacol. 206(1):66–72
- Kurttio, P., Komulainen, H., Hakala, E., Kahelin, H., Pekkanen, J., 1998. Urinary excretion of arsenic species after exposure to arsenic present in drinking water. Arch Environ Contam Toxicol 34(3):297-305
- Lammon, C.A., and. Hood, R.D., 2004. Effects of protein deficient diets on the developmental toxicity of inorganic arsenic in mice. Birth Defects Res B Dev Reprod Toxicol 71(3):124-134
- Luo, Z. D., Zhang, Y. M., Ma, L., Zhang, G. Y., He, X., Wilson, R., Byrd, D. M., Griffiths, J. G., Lai, S., He, L., Grumski, K., Lamm, S. H., 1990. Chronic Arsenicism and Cancer in Inner Mongolia -Consequences of Well-Water Arsenic Levels Greater than 50 mg l-1." In: C. O. Abernathy, R. L. Calderon, and W. R. Chappell, eds., Arsenic Exposure and Health Effects London:Chapman and Hall. 55–68
- Maiti, S., Chatterjee, A.K., 2001. Effects on levels of glutathione and some related enzymes in tissues after an acute arsenic exposure in rats and their relationship to dietary protein deficiency. Arch Toxicol 75(9):531-537
- Maharjan, M., Watanabe, C., Akhtar, S.K., Ahmad, M., 2006. Umezaki, Ryutaro Ohtsuka Mutual interaction between nutritional status and chronic arsenic toxicity due to groundwater contamination in an area of Terai, lowland Nepal

- Mazumder, D.N.G., Haque, R., Ghosh, N., De, B.K., Santra, A., Chakraborty, D., Smith, A.H., 1998. Arsenic levels in drinking water and the prevalence of skin lesions in West Bengal, India. Int. J. Epidemiol. 27, 871-877
- Milton, A.H., Rahman, M., 2002. Respiratory effects and arsenic contaminated well water in Bangladesh. International Journal Environmental Health Research 12: 175-179
- Mitra, S.R., Mazumder, D.N.G., Basu, A., Block, G., Haque, R., Samanta, S., Ghosh, N., Smith, M.MH., von Ehrenstein, O.S., Smith, A.H., 2004. Nutritional factors and susceptibility to arsenic-caused skin lesions in West Bengal, India. *Environ. Health Perspect. 112,* 1104-1109
- Mitra, S.R., Mazumder, G., Basu, A., Block, G., Haque, R., Samantha, S.N., Ghosh, M.M.H., 1996. Nutritional Factors and Susceptibility to Arsenic Caused Lesions in West Bangal, India. Environmental Health Perspectives 2004 Mudir, G. Arsenic poisons 220,000 in India British Medical J. 313 (7048), 9
- Hossain, M.K., Khan, M.M., Alam, M.A., Chowdhury, A.K., Delwar Hossain, M. Ahmed, F., Kobayashi, K., Sakauchi, F., Mori, M., 2005. Manifestation of arsenicosis patients and factors determining the duration of arsenic symptoms in Bangladesh. Toxicol Appl Pharmacol. 208(1): 78-86
- Mohammad, M.R., Mrinal, K.S., Chowdhury, S.A.U.K., Hossain, D.L.A., Das, B., Roy, N., Saha, K.C., Palit, S.K., Chakraborti, D., 2005. Arsenic contamination of groundwater and its health impact on residents in a village in West Bengal,India. Bulletin of the World Health Organization. 83:49-57
- Mok, W.M., and C.M. Wai., 1994. Mobilization of arsenic in contaminated river waters. In: Arsenic in the Environment, Part I: Cycling and Characterization, Edited by J. O. Nriagu. John Wiley and Sons, Inc. New York, NY. pp 99-115.
- Murphy, M.J., Lyon, L.W., Taylor, J.W., 1981. Subacute arsenic neuropathy: clinical and electrophysiological observations. J. Neurol. Neurosurg. Psychiatry. 44: 89
- NAS. 1977. Arsenic Medical and biological effects of environmental pollutants Washington, D.C National Academy of Sciences. pp. 332

- NRCS. and ENPHO., 2001-2003. Drinking water quality improvement program: An overview of arsenic contamination and its mitigation in Nepal Red Cross Society and Environment and Public Health Organization Program Areas
- Nishigori, C., Hattori, Y., Toyokuni, S., 2004. Role of reactive oxygen species in skin carcinogenesis. Antioxid Redox Signal. 6(3):561–570
- NRCS and ENPHO., 2003. Health Impact Study on Population Consuming Arsenic Contaminated Water from Nepal Red Cross Society installed Tube Wells, Rautahat District.
- NRCS., JRCS., ENPHO., 2001. Reports on the Household Survey on the Health Impact of Arsenic Contaminated Ground Water in Parsa District.
- Pi, J., He, Y., Bortner, C., Huang, J., Liu, J., Zhou, T., 2005. Low level, long-term inorganic arsenite exposure causes generalized resistance to apoptosis in cultured human keratinocytes: potential role in skin co-carcinogenesis. Int J Cancer. 116(1):20–26
- Pi, J., Qu, W., Reece, J.M., Kumagai, Y., Waalkes, M.P., 2003. Transcription factor Nrf2 activation by inorganic arsenic in cultured keratinocytes: involvement of hydrogen peroxide. Exp Cell Res. 290(2):234–245
- Rahman, M., Vahter, M., Wahed, M.A., Sohel, N., Yunus, M., Streatfield, P.K., 2006. Prevalence of arsenic exposure and skin lesions. A population-based survey in Matlab, Bangladesh. J Epidemiol Community Health. 60:242–248
- Rahman, M., Tondel, M., Ahmad, S.A., Chowdhury, I.A., Faruquee, M.H. Axelson, O., 1999. Hypertension and arsenic exposure in Bangladesh. Hypertension 33, 74–8.
- Reese, R.G., Jr. 1998. Arsenic. In: United States Geological Survey Minerals Yearbook. Fairfax, VA
- RWSSSP. 2003. A Comprehensive Report on Groundwater Arsenic Contamination - Rural Water Supply and Sanitation Support Program Program Area. Kathmandu, Nepal: Environment and Public Health Organization

- RVWRMP, 2004. Rural Village Water Resources Management Project – Nepal Final project document.
- Safiuddin, M.D., and. Masud Karim 2001. Groundwater Arsenic Contamination in Bangladesh: Causes, Effects and Remediation. Proceedings of the 1st IEB international conference and 7th annual paper meet; 2-3.
- Sah R.B., Thakur, P.K., Gurmaita, H.N., Paudel, K.R., 2003. (Arsenic Research Committee, Department of Geology, Tribhuvan University, Kathmandu, Nepal) Studies for possible natural sources of arsenic poisoning of groundwater in Terai plain of Nepal. Ministry of physical planning and works department of water supply and sewerage (DWSS)/ WHO-Nepal
- Sarkar, A., Mehrotra, R., 2005. Social Dimensions of Chronic Arsenicosis in West Bengal (India). Epidemiology. Volume 16(5) S 68
- Sharma, R.M., 1999. Research study on possible contamination of groundwater with Arsenic in Jhapa, Morang, and Sunsari districts of Eastern Terai of Nepal. Report of the WHO project, DWSS, Govt of Nepal
- Shrestha, R.R., Shrestha, M.P., Upadhyay, N.P., Pradhan, R., Khadka, R., Maskey, A., Maharjan, M., Tuladhar, S., Dahal, B.M., Shrestha, K., 2003. Groundwater arsenic contamination, its health impact and mitigation program in Nepal. J Environ Sci Health Part A Tox Hazard Subst Environ Eng 38: 185–200
- Smit, E., Nieto, F.J., Crespo, C.J., Mitchell, P., 1999. Estimates of animal and plant protein intake in US adults: results from the Third National Health and Nutrition Examination Survey, 1988-1991.J Am Diet Assoc 99(7):813-820.
- Smith, A., Hopenhayn-Rich, C., Bates, M., Goeden, H., Hertz-Picciotto, I., Duggan, H., Wood, R., Kosnett, M., Smith, M., 1992. Cancer risks from arsenic in drinking water. Environ Health Perspect. 97: 259-267
- Smith, A.H., Arroyo, A.P., Mazumder, D.N., Kosnett, M.J., Hernandez, A.L., Beeris, M., 2000. Arsenic-induced skin lesions among Atacameno people in Northern Chile despite good nutrition and centuries of exposure. Environ Health Perspect 108(7):617-620

- Soma, R., Mitra, D.N., Guha Mazumder, D.N., Arindam B., Gladys, B,, Haque, R., Samanta, S., Ghosh, N.,Smith, H., Ondine, S., Ehrenstein,V., Smith A.H., 2004 Nutritional Factors and Susceptibility to Arsenic-Caused Skin Lesions in West Bengal, India, *Environmental Health J.* 112(10)
- Subash, C.M., Chakraborti, D., Pati, S., Mrinal K., Gupta, S,. Mohammad, M.R., Uttam, K., Chowdhury, D.L., Chitta, R.C., Chakraborti, A.K., Gautam, K.B., 2003. Arsenic Groundwater Contamination in Middle Ganga Plain, Bihar, India: A future Danger? Environmental Health Perspectives Volume 111, Number 9, July
- Tandukar, N., 2000. Arsenic Contamination in Groundwater in Rautahat District of Nepal: An Assessment and Treatment; Kathmandu, Nepal
- Thornton, M.J., 2005. Oestrogen functions in skin and skin appendages. Expert Opin Ther Targets. 9(3):617–629
- Tondel, M., Rahman, M., Magnuson, A., Chowdhury, I.A., Faruquee, M.H., Ahmad, S.A., 1999. The relationship of arsenic levels in drinking water and the prevalence rate of skin lesions in Bangladesh. Environ Health Perspect. 107:727–729
- Tseng, W.P., 1977. Effects and dose–response relationships of skin cancer and blackfoot disease with arsenic. Environ Health Perspect. 19:109–119
- Tseng, W.P., Chu, H.M., How, S.W., Fong, J.M., Lin, C.S., Yeh, S., 1968. Prevalence of cutaneous cancer in an endemic area of chronic arsenicism in Taiwan. J Nat Cancer Inst, 40:453-463
- Uddin, A.N., Burns, F.J., Rossman, T.G., 2005. Vitamin E and organoselenium prevent the cocarcinogenic activity of arsenite with solar UVR in mouse skin. Carcinogenesis. 26(12):2179–2186
- USEPA. 1998. Locating and Estimating Air Emissions from Sources of Arsenic and Arsenic Compounds. United States Environmental Protection Agency Office of Air Quality Planning and Standards, Research Triangle Park, NC. Document No. EPA-454-R-98-013
- Vahter, M., and Marafante, E., 1987. Effects of low dietary intake of methionine, choline or proteins on the biotransformation of arsenite in the rabbits. *Toxicol. Lett. 37,* 41-46.

- Vahter, M., Berglund, M., Akesson A., Liden C., 2002. Metals and women's health. Environ Res. 88(3):145–155
- Vahter, M.E., Li, L., Nermell, B., Rahman, A., Arifeen, E.l., Rahman, S.M., 2006. Arsenic exposure in pregnancy: a population-based study in Matlab, Bangladesh. J Health Popul Nutr 24(2):236-245
- Vahter, M., and Marafante, E., 1987 Effects of low dietary intake of methionine, choline or proteins on the biotransformation of arsenite in the rabbit. Toxicol. Lett. 37, 41–6
- Valentine, J.L., Campion, D.S., Schluchter, M.D., Massey, F.J., 1982. Arsenic effects on human nerve conduction. In: Proceedings of the 4th International Symposium on Trace Element Metabolism in Man and Animals, held in Perth, Western Australia, May 11–15, 1981. J.M. Gawthorne, J.M. Howell, and C.L. White (eds.). Springer-Verlag, Berlin. p. 409.
- Waalkes, M.P., Liu, J., Ward, J.M., Diwan, B.A., 2004. Mechanisms underlying arsenic carcinogenesis: hypersensitivity of mice exposed to inorganic arsenic during gestation. Toxicology. 198(1–3):31–38
- Wagner, S.L., Maliner, J.S., Morton, W.E., Braman, R.S., 1979. Skin cancer and arsenical intoxication from well water. Arch. Dermatol. 115: 1205
- Watanabe, C., Inaoka, T., Kadono, T., 2001. Males in rural Bangladeshi communities are more susceptible to chronic arsenic poisoning than females: analyses based on urinary arsenic. Environ Health Perspect 109:1265–70
- Welch, A.H., Lico, M., Hughes, J., 1988. Arsenic in ground water of the western United States. Ground water. 26(3): 333-347.
- Wesbey, G., and Kunis, A., 1981. Arsenical neuropathy. Ill. Med. J., 150: 396
- WHO. 2001. Environmental Health Criteria 224: Arsenic and Arsenic compounds. WHO, Geneva
- WHO. 2002. *Children's health and the environment: a review of evidence*. Copenhagen: World Health Organisation, Regional Office for Europe.
- World Bank report (Environment and Social Unit- South Asia Region, Water and Sanitation Program (WSP) - South and East Asia) 2005. Towards a More effective Operational Response: Arsenic Contamination of Groundwater in South and East Asian Countries volume II Technical Report

- Wu, M.M., Kuo, T.L., Hwang, Y.H., Chen, C.J., 1989. Dose-response relation between arsenic concentration in well water and mortality from cancers and vascular disease. Am J Epidemiol, 130: 1123-1132
- Yan-Chu, H., 1994. Arsenic Distribution in Soils. Chapter 2 in Nriagu, J.O., Ed., Arsenic in the Environment Part I: Cycling and Characterization. New York: John Wiley & Sons, Inc. pp 17-49
- Yang, C.Y., Chang, C.C., Tsai, S.S., Chuang, H.Y., Ho, C.K., Wu, T.N., 2003. Arsenic in drinking water and adverse pregnancy outcome in an arseniasis-endemic area in northeastern Taiwan. Environ Res. 91(1):29–34
- Yang, T.H., Blackwell, R.Q., 1961. Nutritional and environmental conditions in the endemic blackfoot area. Formos Sci 15:101-129
- Zaldivar, R., Ghai, G.L., 1980. Clinical epidemiological studies on endemic chronic arsenic poisoning in children and adults, including observations on children with high- and low-intake of dietary arsenic. Zentralbl Bakteriol. 1. Abt Originale B: Hygiene, Krankenhaushygiene, Betriebshygiene, Praventive Medizin 170:409–21.
- Zaldivar, R., and Guillier, A., 1977. Environmental and clinical investigations on the endemic chronic arsenic poisoning in infants and children. Zbl. Bakt. Hyg. I Abt. Orig. B. 165, 226 – 34.

Annex-I
PHOTOGRAPHS

Plate: 1
Melanosis in Chest

Plate: 2
Melanosis in Chest

Plate: 3
Melanosis in Chest

Plate: 4
Melanosis in Trunk

Plate: 5
Melanosis in Trunk

Plate: 6
Melanosis in Trunk

Plate: 7
Melanosis in Limb

Plate: 8
Melanosis In limb

Plate: 9
Melanosis in Trunk

Plate: 10
Melanosis in Chest

Plate: 11
Melanosis in Chest

Plate: 11
Melanosis in Trunk

ANNEX II

Semi-structured Questionnaire

Name of the respondent: Date:

Sex: Questionnaire No:

Age: Enumerator:

Education: Signature:

Occupation: V.D.C:

Family Size: Ward No. :

Monthly Income: District:

Age of Tubewell:

General Information

1. At present, where do you collect your water?

☐ Tubewell ☐ Pond / River/Canal ☐ Well

☐ Rainwater Others (Specify) ---------------------------

If tubewell, for what purpose do you use tubewell water?

☐ For everything ☐ Utensils ☐ drinking

☐ Cooking ☐ Washing ☐ Bathing

☐ Feeding cattle ☐ Irrigation

☐ Others (Specify) ---------------------------------

2. How many glasses of water do you drink each day? (1 glass =250ml)

☐ 1 - 3 liters ☐ 4 - 6 liters ☐ 7 - 10 liters

3. Do you know for what reasons tube well water might not be safe for drinking and cooking?

☐ Arsenic ☐ Do not know

☐ Others (Specify) ---------------------------------

4. How long are you drinking?

☐ Years ☐ month ☐ days

6. Do you purify your drinking water?

☐ Yes ☐ No

If yes, how do you purify?

☐ By boiling ☐ Using medicine ☐ Filters

☐ Others (Specify) ---------------------------------

7. Who taught you about this method?

☐ Self ☐ Health Workers ☐ NGO Workers

☐ Others (Specify) ----------------------------------

8. Why you do not purify your drinking water?

☐ Do not think its necessary ☐ Expensive

☐ No time ☐ others (Specify) --------------------------

5. Have you heard that Arsenic has been found in tubewell water?

☐ Yes ☐ No

If yes, where have you heard it?

☐ Television ☐ Radio ☐ Newspaper

☐ NGO ☐ Health Worker ☐ Relatives

☐ Others (Specify) --------------------------------

6. Do you know that drinking arsenic contaminated water can be harmful for health?

☐ Yes ☐ No

If yes, Name the Symptoms: --

9. What is the main water stress in your locality?

☐ Lack of enough water (Quantity) ☐ Lack of safe water (Quality)

10. What can you immediately do to collect arsenic safe drinking water?

☐ Not applicable (own tubewell safe) ☐ Not applicable (tubewell not tested)

☐ Filter personal tubewell ☐ Dig new tubewell

☐ Increasing depth of tubewell ☐ Collect water from others

☐ Safe tubewell ☐ Pond water

☐ ☐

Canal/ River No money, no plans

☐ Rain water ☐ others (Specify) ---------------------------------

11. In your opinion, what can be the long term solution to the arsenic problem?

☐ Filter surface water ☐ Rainwater harvesting

☐ Community based pond ☐ Use deeper tubewell

☐ Others (Specify) -------------------------------------

12. In your opinion, who should be responsible for action to solve the water crises?

☐ Self ☐ Community ☐ Government

☐ NGOs ☐ UN Aid agencies ☐ others (Specify) ------------

14. Do you think people avoid you or anyone you know because of this disease?

☐ Yes ☐ No

15. What is your family month's medical expenditure?

Rs -----------------------

16. What do you have to do to cope with this expenditure?

☐ Enough money to meet expenditure ☐ less money to buy clothes

☐ Less money to buy ☐ other household expenditure

☐ Less money for education ☐ Fewer saving

☐ Have to take ☐ others (Specify) ------------------------------------

ANNEX - III
Health Survey Data Sheet

1. Introduction: Date:

Development Region: District:

VDC/City: Ward No. /Village:

Household No.: Tubewell No.:

2. Name of the Householder/Informer:

3. Level of Arsenic in drinking water

1. Safe (<10ppb) 2. Contaminated (>10ppb)

4. Economic Status of the household:

Low ☐ Medium ☐ High ☐

Members of household (Name)	Age	Sex	Years of education	Skin disease				Remarks
				Arsenicosis			Others	
				1	2	3		
1.								
2.								
3.								
4.								
5.								
6.								
7.								

1. Melanosis: a) sole b) palm c) trunk d) limb e) chest

2. Keratosis: a) sole b) palm

3. Oedema:

______________ ________________ ______________

Interviewed by: Cross-checked by: Conformed by: