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Research Study on Possible Contamination of Groundwater with Arsenic in Jhhapa, Morang, and Sunsari Districts of Eastern Terai of Nepal

FINAL REPORT

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Executive Summary

A total of 268 water samples were tested for probable arsenic contamination from Jhhapa, Morang, and Sunsari districts of Eastern Terai of Nepal. The samples were tested in the laboratory of Nepal Environmental and Scientific Services (an accredited laboratory from Department of Standards and Metrology) in Kathmandu.

Table ES-1 shows the result obtained for arsenic concentration of groundwater in the study area.

Table ES-1: Laboratory Result of Cumulative Arsenic Contamination of Groundwater in the Study Area

District	No. of Samples Tested	No. of Samples found in concentration range (mg/L)			
		Not Detected, < 0.005	0.005-0.01	0.01-0.05	> 0.05
Jhhapa	92	86	3	3	0
Morang	90	79	2	9	0
Sunsari	86	70	4	10	2

The result for Jhhapa district shows that there are 3 wells with arsenic concentration range exceeding WHO guideline value of 0.01 mg/L. However, they do not exceed India and Bangladesh standard of 0.05 mg/L. In Morang, 9 samples have exceeded WHO guideline value. The scenario is found bit different for Sunsari. With 12 values exceeding WHO guideline, 2 of them still exceed India and Bangladesh standard. Moreover, area of contamination for Sunsari district shows that the "hot pocket" basically lies close to River Koshi.

Although not found spread widely, few cases of symptoms similar to arsenicosis had been observed in the study area.

Some recommendations have been made in the Report together with identification of future research areas.

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List of Acronyms and Abbreviations

AAN	Asia Arsenic Network
AAS	Atomic Absorption Spectrophotometer
ADB	Asian Development Bank
AIIHPH	All India Institute of Hygiene and Public Health
BGS	British Geological Survey
CBS	Central Bureau of Statistics
DDC	District Development Committee
DPHO	District Public Health Office
DTW	Deep Tube Wells
DWSO	District Water Supply Office
DWSS	Department of Water Supply and Sewerage
FY	Fiscal Year
GWB	Government of West Bengal
IARC	International Agency for Research on Cancer
MDL	Minimum Detection Limit
MOHPP	Ministry of Housing and Physical Planning
NEERI	National Environmental Engineering Research Institute (India)
NIOSH	National Institute for Occupational Safety and Health (USA)
NIPSOM	National Institute for Preventive and Social Medicine
NWSC	Nepal Water Supply Corporation
PHED	Public Health Engineering Department
SDDC	Silver Diethyldithiocarbamate
SOES	School of Environmental Studies at Jadavpur University
STM	School of Tropical Medicine
STW	Shallow Tube Wells
UNICEF	United Nations Children's Fund
USEPA	United States Environmental Protection Agency
USPHS	United States Public Health Service
VDC	Village Development Committee
WHO	World Health Organisation
WS	Water Supply
m^3	*cubic metres*
kg	*kilogram*
L	*Litre*
μg	*microgram*
mg	*milligram*
mL	*millilitre*
ng	*nanogram*
ppb	*part per billion*
ppm	*part per million*

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1.0 Introduction

1.1 Background of the Study

Arsenic - one of the oldest poisons known to mankind and a known human carcinogen, has created serious contamination of the environment and has caused much mass poisoning throughout the world. At present, arsenic contamination of groundwater in the neighbouring Indian State of West Bengal and adjacent Bangladesh has emerged as the biggest arsenic-calamity in the world.

Man's exploitation of the nature, as for example, the overuse of groundwater for irrigation, geothermal power plants and mining operations and until recently use of several forms of arsenic-laden pesticides has seriously threatened the wellbeing of mankind and the pristine state of the environment.

Now, as a lesson for mankind, the present situation has created an increased consciousness among responsible citizens and governments worldwide about health and the environment. The present situation has also warranted that natural resources be utilized and exploited with topmost regard for health and environmental consequences. Moreover, the dimensions of the damage thus incurred in the environment have demanded sound scientific information and affordable mitigation measures in addressing these consequences.

This Report is an outcome of the agreement signed on 26th May 1999 between the Department of Water Supply and Sewerage and the World Health Organization (WHO) to conduct a research study on "Possible Contamination of Groundwater with Arsenic in Jhhapa, Morang, and Sunsari districts of Eastern Terai of Nepal"

Since this study is first of its kind in the context of Nepal, the understanding of the task is based on review of terms of reference (TOR), relèvant literatures, standards and practices applied and followed by institutions in neighbouring India and Bangladesh.

1.2 Objective of the Study

General objective of this study is to draw a concept regarding the occurrence of this substance in the groundwater of Nepal and more specifically in the groundwater of Jhhapa, Morang, and Sunsari districts of the Eastern Terai of Nepal.

Specific objectives of this study are listed hereunder:

1. Review of the findings of the institutions namely WHO's regional office in New Delhi and other related country-institutions regarding arsenic crisis in the area,
2. Determine its occurrence and concentration (sufficient to influence drinking water quality) in the study area,
3. Identify, if any, negative health effects from consumption of groundwater, and
4. Make suggestions and recommendations based on findings of the study.

1.3 Expected Outputs

Expected outputs of this study are:

- Scenario of groundwater contamination from Arsenic reviewed,
- Occurrence and concentration of arsenic sufficient to influence drinking water quality identified,
- Areas with groundwater possibly contaminated with Arsenic identified, and
- Negative health effects from consumption of groundwater identified.

1.4 Methodology

This study is conducted within the framework of the following methodology:

1. Critical review of literatures related to arsenic poisoning, review of works accomplished by related country-organizations of the region;
2. Field visit, data collection, and sample collection; formats developed for this purpose are annexed,
3. Testing:
   Tests conducted on site with the aid of arsenic detection field-kits for quick screening and spectrophotometry method for more accurate and detail analysis in the laboratory;
4. Result analysis / interpretation; and
5. Report generation.

2.0 Arsenic- Fundamental Facts

2.1 Introduction

Arsenic, As, is a metallic main group element, found in Group V(b) of the Periodic Table with Atomic Number 33, and relative atomic mass 74.92. Arsenic was first isolated as the metal by Albertus Magnus about 1250 AD. Arsenic, also an oldest known human poison, is reported to have six very specific characteristics (Azcue & Nrjagu, 1994 in Dahi, 1997a):

- It is a virulent poison on acute ingestion, 76 mg As (III) is considered to be lethal to adults.
- It is extremely toxic on long term exposure to very low concentrations.
- It is not visible in water and food. Even heavily contaminated water may be clear and clourless.
- It has no taste. Even heavily contaminated water may have a pleasant taste.
- It has no smell even at deadly concentrations.
- It is difficult to analyse, even when occurring in water in concentrations double as high as the WHO guideline.

Arsenic is found in the minerals as oxides, sulphides and arsenides:

- Arsenolite, As_4O_6,
- Realgar, As_4S_2,
- Orpiment, As_2S_2,
- Mispickel or Arsenical Pyrite, FeAsS,
- Cobaltite or Cobalt Glance, CoAsS,
- A Tin White Cobalt, $CoAs_2$,
- Arsenical Iron, AsFe and As_4Fe_3,
- Nickel Glance, NiAsS,
- Kupfernickel, NiAs; and etc.

Arsenic is similar to Calcium in its chemical properties. Arsenic in its elemental form exhibits allotropy and three forms are known:

1. *gamma*-Arsenic which is also known as grey-Arsenic, is the ordinary form and it is a steel-grey metallic substance with a bright lustre,
2. *beta*-Arsenic is formed when the gamma-Arsenic is heated in a stream of Hydrogen and black crystals of beta-Arsenic are deposited nearest the hot end of the tube, and
3. *alpha*-Arsenic is formed when the gamma-Arsenic is heated in a stream of Hydrogen and a yellow powder of alpha-Arsenic is deposited in the cooler part of the tube. Alpha-Arsenic is very sensitive to light and reverts to gamma-Arsenic.

Soluble arsenic occurs in natural waters only in As (V) and As (III) oxidation states. Although both organic and inorganic forms of arsenic have been detected, organic species (methylated arsenic) are rarely present at concentrations larger than 1 μg/L and are generally considered of little significance compared with inorganic arsenic species in drinking water treatment (Edwards, 1994). However, Susheela (1999) is of the view that both organic and inorganic arsenic are found in natural water in the ratio of 1:1.

Furthermore, the pentavalent arsenate species are found mostly in an oxygen-rich aerobic environment, whereas the trivalent arsenite species are found mostly in anaerobic environments such as groundwater.

Arsenic has a wide variety of uses in several industries. It is used:

- in the manufacture of arsenic compounds;
- in preparing hardened lead shot;
- in alloys used for making boiler tubes;
- in insecticides and weed-killers; and
- in the electronics industry in the manufacture of semiconductors.

Arsenic is detected by the green coloration of Copper Arsenide, CuAs, which is formed on the surface of Copper foil when the arsenic compound is heated with hydrochloric acid.

2.2 Carcinogenicity and Health Effects

An IARC working group reported that there is sufficient evidence for the carcinogenicity of inorganic arsenic compounds in humans. Many cases of skin cancer have been reported among people exposed to arsenic through medical treatment with inorganic trivalent arsenic compounds. In some instances, skin cancer has occurred in combination with other cancers, such as liver angiosarcoma, intestinal and urinary bladder cancers and meningioma. An association between environmental exposure to arsenic through drinking water and skin cancer has been observed and confirmed. The Department of Health and Human Services (USA) has determined that arsenic is a known carcinogen. IARC has determined that arsenic is carcinogenic to humans. Both the US EPA and National Toxicology Program (USA) have classified arsenic as a known human carcinogen.

Although animals fed with a normal amount of arsenic showed better results than their counterparts that had been fed with unusually low concentrations of arsenic no cases of arsenic deficiency in humans have ever been reported (USPHS, 1993).

Graef (1995) confirms that arsenic produces its toxicity by binding with tissue sulfhydryl groups. The early manifestations of arsenic poisoning are: muscle weakness and aching, skin pigmentation in eyelid, nipples, chest and axilla; skin oedema, garlic odour of breath and perspiration; excessive salivation and sweating; generalized itching; sore throat; numbness; liver enlargement and kidney dysfunction (Susheela, 1999). Health effects from consuming arsenic-contaminated drinking-water are delayed. Skin lesions are generally first, and appear after a minimum exposure of approximately 5 years (Fact Sheet, 1999). Arsine gas is absorbed through the lungs and it combines with the globin chain of hemoglobin in red blood cells. Signs and symptoms of toxicity include nausia, vomiting, diarrhea, apprehension and malaise, tachycardia, and dyspnea.

Groups of arsenic compounds can be listed as follows in decreasing order of toxicity (Penrose, 1974 cited in Drinking Water and Health):

Arsines > Arsenite (inorganic) > Arsenoxides > Arsenate > Pentavalent arsenicals > Arsonium compounds > Metallic arsenic.

Human exposure to Arsenic sufficient to cause severe toxicosis usually occurs through ingestion of contaminated food or drink. The trivalent arsenite species are found mostly in anaerobic environments such as groundwater, as arsenic, a Class-A carcinogenic substance is the most serious contaminant in drinking water. Epidemiological studies in areas where drinking water contained 0.35-1.14 mg/L arsenic elevated risks for cancer of the bladder, kidney, skin, liver, lung, and colon in both men and women. The lethal dose of arsenic is 1-4 mg/kg of body weight. Whereas for children, as little as 2 mg/kg of body weight can be lethal (Graef, 1995).

Occupational exposure to inorganic arsenic, especially in mining and copper smelting has quite consistently been associated with an increased risk of cancer. An almost tenfold increase in the incidence of lung cancer was found in workers most heavily exposed to arsenic, and relatively clear dose-response relationships have been obtained with regard to cumulative exposure.

Links have also been established between arsenic poisoning and malnutrition. Findings of a recent survey conducted by the Dhaka Community Hospital Trust over 18 months has revealed that most arsenic affected were malnourished poor people (Web-site[a]).

2.3 Exposure Pathways, Fate and Transport

The primary routes of potential human exposure to arsenic and certain arsenic compounds are inhalation, ingestion, and dermal contact. NIOSH estimated that 1.5 million industrial workers are potentially exposed to arsenic and its compounds during manufacturing and processing operations. Because arsenic is a natural part of the environment, low level of arsenic are present in soil, water, food, and air. Soil usually contains the most, with average levels of about 5000 ppb. Levels in food are usually about 20 – 140 ppb and levels in water are about 2 ppb (USPHS, 1993). Levels in air are usually 0.02-0.10 $\mu g/m^3$.

In addition to the normal levels of arsenic in air, water, soil, and food one is exposed to higher levels in several ways such as the following (USPHS, 1993):

- Some areas in the earth contain unusually high natural level of arsenic in rock, and this can lead to unusually high levels of arsenic in soil or water. Some hazardous waste sites contain high levels of arsenic. If the material is disposed off, it can get into surrounding air, water, and soil.
- A person working in an occupation that involves arsenic production or use (for example, copper or lead smelting, wood treating, pesticide application) could be exposed to above-average level of arsenic during the work, and
- Until recently several kinds of products used in the home (rat poison, ant poison, weed killer, and some medicines) had arsenic in them.

Arsenic can enter the environment in several ways. Even though it does not evaporate, arsenic can get into air as dust. This can happen when smelters heat ores containing arsenic, when any material is burnt containing arsenic, or when wind blows soil that contains arsenic into the air. Once in the air, the arsenic particles travel with the wind for a while, and then settle back to the ground. Most arsenic compounds dissolve in water and then gets into lakes, rivers, and underground water by dissolving in rain or snow, or through the discharge of industrial wastes. Some of the arsenic sticks to the sediment on the bottom of the lake and rivers and some will be carried along by the water. Arsenic is not broken down or destroyed in the environment. However, it can change from one form to another by natural chemical reactions and also by the action of bacteria that live in soil and water. Although some fish or shellfish build up arsenic in their tissues, most of this is in non-toxic form.

Two main theories – *Pyrite Oxidation* and *Oxyhydroxide Reduction* have been regarded as source to contamination of groundwater with arsenic (Fact Sheet, 1999). In the first, as a response to pumping, air or water with dissolved oxygen penetrates into the ground, leading to decomposition of the sulfide minerals and release of arsenic. In the latter case, arsenic is naturally transported and adsorbed onto fine-grained iron or manganese oxyhydroxides that slowly break down. The second theory has been accepted as the most likely explanation of this phenomenon. Further, it has been believed that the large-scale withdrawal of groundwater causes fluctuation of the water-table and regular intake of oxygen within the pore space of the sediments and this inflow breaks down sulfides in the arsenic-laden pyrite rock through oxidization and releases arsenic into the water (Web-site[b]).

Both natural and anthropogenic sources cause arsenic get into the water-bodies. Leaching of dissolved arsenic from arsenic-rich soil to the ground is a major source of groundwater pollution. Mostly surface waters and in some cases groundwater too are contaminated by arsenic through anthropogenic nature. Use of arsenic-laden pesticides, smelting non-ferrous metal ores particularly copper, thermal electric power plant, super phosphate fertilizer made by treatment of phosphorite with sulfuric acid are the main pollutants of surface waters with arsenic.

2.4 Metabolism

Arsenic is radio-opaque and is seen on x-ray of the abdomen. It is also detected on hair and nails for months following exposure. Arsenic is absorbed through the skin, lungs, and gastrointestinal tract. Inorganic (trivalent) compounds are absorbed more readily than organic (pentavalent) forms, with greater than 80 % of an ingested dose absorbed by the gastrointestinal tract (Graef, 1995). Arsenic is distributed from blood to liver, kidney, lungs, spleen, and intestines within 24 hours of ingestion and to skin, hair, and bones within 2 weeks. Inorganic arsenic does not cross the blood-brain barrier but does cross the placenta. Between 5 to 10 % of arsenic is excreted in feces, and 90 to 95 % is excreted in urine.

2.5 Global Scenario of Arsenic Problem

Arsenic contamination of drinking water has been reported from Asia and many other parts of the world. Besides India and Bangladesh, water sources from Andes mountain in Chile, community water supplies in western part of USA, drinking water supply in Cordoba province of Argentina, and southwest coast of Taiwan have provided globally the evidence of poisoning effects of arsenic in human health. The presence of arsenic in drinking water has also been reported from Japan, Latin America, Hungary, Greece, Russia, Mexico, Thailand, China, the Philippines, and Inner Mongolia (WHO, 1997; Drinking Water and Health, 1977).

2.6 Standards and Guideline Values for Arsenic in Drinking Water

Reports have shown that there is a wide variation in guideline values set for arsenic in different countries. In 1993, the World Health Organization (WHO) had established 0.01

mg/L as a provisional guideline value for arsenic in drinking water revising it downward from an earlier value of 0.05 mg/L. Many countries have either kept this as the national standard or as an interim target before tackling populations exposed to lower but still significant concentrations in the 0.01-0.05 mg/L range. This latest edition of the guideline value developed by WHO is provisional because of the lack of suitable testing methods (Fact Sheet, 1999).

The WHO guideline value for arsenic of 0.01 mg/L is an upper-bound estimate of excess skin cancer risk of roughly 6 additional skin cancer cases per 10,000 population from consumption, over a lifetime of 70 years, of 2 liters of water per day containing 0.01 mg/L of arsenic (ITN, 1996). Similarly, consideration of the new risks at the maximum contaminant level of 0.05 mg/L arsenic suggests a lifetime risk of dying from arsenic induced cancers as high as 13/1,000 people at 1 L/day (Smith, 1992 in Edwards, 1994).

Table 2.1 shows acceptable limits of arsenic in drinking water established by some of the countries and regulatory bodies:

Table 2.1: Acceptable Limit for Arsenic in Drinking water

Country / Agency	Maximum Acceptable Concentration (MAC, mg/L)	Remarks
USA	0.05	Considering downward revision to 2-20 μg/L
USEPA	0.01	
Canada	0.025 Interim	
EEC	0.05	
Great Britain	0.05	
Germany	0.01	Lowered from 0.04 mg/L in 1996
Russia	0.05	
Japan	0.01	Lowered from 0.05 mg/L in 1992
Taiwan	0.05	
China	0.05	
India	0.05	
Bangladesh	0.05	
WHO	0.01	Provisional guideline value

Source: Sayre, I. M., International Standards for Drinking Water, Journal AWWA 80, 53-60.1988; Edwards, 1994; ITN, 1996

2.7 Testing for Arsenic

2.7.1 Laboratory Testing

The analysis for arsenic requires determination of total As^{3+} and As^{5+}. Traditionally, measuring arsenic in drinking water requires laboratory analysis through spectrophotometric measurement using silver diethyldithiocarbamate (SDDC) or using atomic absorption spectrophotometers (AAS) with special facilities and trained staff. The latter method has an absolute detection limit of 10 ng, which for a 20-mL sample, provides a solution detection limit of 0.5 μg/L-a hundred times less than the higher-ever drinking water standard - 50 μg/L (Drinking water and Health, 1977). The method applies to both inorganic and organic arsenic. The SDDC method involving generation of arsine, colour development with SDDC and measuring the colour spectrophotometrically, still remains the choice in most of the public health laboratories.

In the SDDC method, the inorganic arsenic is reduced to arsine by zinc in acid solution in an arsine generator. The arsine is then passed through a scrubber containing glass wool impregnated with lead acetate solution and into an absorber tube containing SDDC dissolved in pyridine. In the absorber, arsenic reacts with the silver salt forming a soluble red complex which is measured spectrophotometrically (Pande and Hasan, 1978). Pande (1980) reports further improvement of this method by using morpholine as a substitute for pyridine. Since pyridine has a characteristic pungent and nauseating odour and is often objectionable to the analyst and his or her associates morpholine can also be used instead of pyridine for preparing the SDDC reagent, which is less expensive, and without pungent odour. The limit of detection thus is up to 0.002 ppm.

Some of the available AAS methods for arsenic detection are:

1. *AAS (Continuous Hydride Generation)*: This is a standard and a reliable method for arsenic analysis in water at the ppb concentration levels approved by US EPA. An MDL as low as 0.002 mg/L can be obtained in this method.
2. *AAS (Graphite Furnace with Background Corrector):* This method, also approved by US EPA is good for arsenic analysis at ppb level. This method is regarded even better than AAS-hydride generation as no chemicals and sample pretreatment are needed.

Apart from the ones mentioned above, Electro-chemical method, Visible Spectrophotometry, Total Reflection X-ray Fluorescence system, Instrumental Neutron Activation Analysis, Proton Induced X-ray Emission, and HG-Inductively Coupled Plasma methods are also used in detecting arsenic in water samples.

2.7.2 Field Testing

Various field-kits have also been developed for finding out approximate information and rapid assessment of the problem of arsenic in field thus narrowing areas for actual laboratory testing. Khaliquzzaman et al. (1999) report that field kits used in Bangladesh consist of a crude hydride generation system using $SnCl_2$, KI, Zn dust and HCl. The reagents are added to the water in a tube and the arsine gas produced changes the colour of the Mercury Bromide ($HgBr_2$) indicator paper.

NEERI together with WHO has made assessment of some field kits (NEERI/WHO, 1998). In this connection, five different kits developed by different institutions currently being used in this field namely AAN (Japan), E-Merck (Germany), Aqua (India), NIPSOM (modified AAN Japan), and AIIHPH (modified version) had been assessed.

Brief description of the kits follows hereunder:

AAN Kit: it is compact, made of durable material and is of light weight. The lowest detection limit of arsenic with this kit is 0.02 mg/L. the kit has no provision for elimination of sulfide interference in the estimation of arsenic.

E-Merck Kit: it is also compact, made of durable materials and is of light-weight. The lowest detection limit is 0.10 mg/L of arsenic and this can be further reduced to 0.05 mg/L by doubling the volume of test samples and the quantity of reagents. The kit has no provision for elimination of sulfide interference.

Aqua Kit: it is relatively bulky and heavier and is meant for detection of arsenic concentration equal to or more than 0.05 mg/L. This kit has provision for elimination of interference due to sulfide, if any.

NIPSOM Kit: is a modified version of AAN (Japan) kit with the components made locally in Bangladesh. The detection range is between 0.02-0.7 mg/L. The kit has no provision for elimination of interference due to sulfide. The kit enables completion of the test in about 5 minutes, the lowest among the kits.

AIIHPH Kit: it is bit bulky and is capable of detecting arsenic in concentrations equal to or more than 0.05 mg/L. The kit has provision for elimination of interference due to sulfide.

Recently, NEERI itself has also developed a field-kit for arsenic determination. The kit can detect arsenic in the range of 0.01 mg/L to 1.0 mg/L. The kit, however, has low precision and accuracy at arsenic level ≤ 20 ppb, but for levels ≥ 50 ppb the kit is precise and accurate. As reported during a visit to NEERI, the prototype model of the kit is ready for commercialisation and the cost would be around USD 75.00.

3.0 Arsenic Contamination of Groundwater in Neighboring Countries

Unfortunately, one of the large-scale arsenic toxicities is found in neighboring West Bengal State of India and Bangladesh. This Study attempts to discuss some of the key issues related to arsenic contamination of groundwater in those areas keeping in mind that it would be helpful for policy makers and future researchers in addressing the problems associated with this toxic contaminant.

3.1 Arsenic Contamination of Groundwater in India

Based on a study undertaken by several agencies notably AIIPH (Calcutta), STM (Calcutta), PHED (GWB), and etc., the Ganga-Brahmaputra delta having a near surface succession of quaternary sediments of varying thickness are found to be the arsenic affected area (AIIHPH, 1997). The arseniferous belt lies entirely within the Upper delta plain characterised by a series of meander belts formed by rivers.

3.1.1 Extent and magnitude of the Problem

There is no consensus on the extent and magnitude of the problem and the number of people affected. However, water quality analysis carried out by different agencies upto 1995 indicated that a total of 61 blocks in Malda, Mursidabad, Nadia, North 24-Parganas, South 24-Parganas, Burdwan, Howrah, and Hooghly districts are affected with arsenic contamination in groundwater. Current estimates suggest that out of four million people living in the affected areas at least 800,000 might be potentially exposed. A preliminary estimate suggests that 15,000 of them may be already having typical arsenicosis symptoms. The problem of arsenical dermatosis from tubewell water was first discovered clinically by Dr. K. C. Saha, Retired Professor of Dermatology, School of Tropical Medicine, Calcutta in 1983.

Of the various agencies studying the arsenic contamination phenomenon in West Bengal, one survey conducted by SOES, Jadavpur University reports that nearly 200,000 people were suffering from arsenic-related skin ailments suspecting this number to increase as more and more areas are probed (Sunday, 1995).

In West Bengal, studies conducted till the beginning of 1998 reveal that 68 blocks in eight districts have arsenic contaminated tubewells.

3.1.2 Probable Causes of Contamination

Many studies have been conducted to determine the actual cause of arsenic contamination of groundwater in this area. The actual cause of arsenic pollution is believed to be natural rather than man-made. Mandal (1998), on the basis of available literature study and bore-hole sediment analysis, reports that the reason of arsenic in groundwater of West Bengal is due to heavy groundwater withdrawal. Aerating the aquifer, the oxygen decomposed the pyrite (FeS_2) rich in arsenic and the acid released leached out the arsenic in soluble form in groundwater.

Given that arsenic was already there in the sediments why did it start appearing in harmful quantities in the groundwater, now? Mallick and Rajagopal (1995) are also of the similar view that the aerobic zone has increased with increased supply of oxygen and is in contact with the said sediment layers. The cause of this increased supply of oxygen again may be due to the development of heavy duty tubewells causing extension of vadose zones, that is unsaturated air-water mixed zones, during pumping, thereby supplying more oxygen and dissolved air, naturally with oxygen as an important constituent, to the groundwater.

Resulting arsenic contamination of groundwater with enhanced aerobic condition with more dissolved oxygen is shown in Figure 3.1.

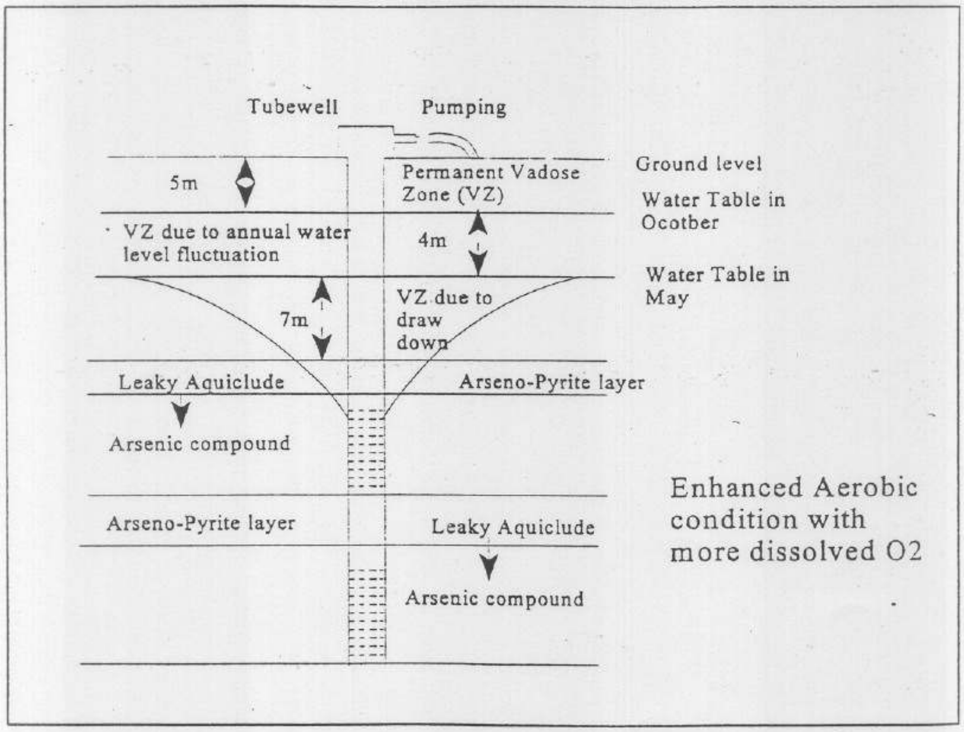


Fig. 3.1 Aerobic condition in groundwater around a heavy duty tubewell in eastern part of West Bengal (Source: After SOES)

3.2 Arsenic Contamination of Groundwater in Bangladesh

The contamination of groundwater by arsenic in Bangladesh was first discovered by the Department of Public Health Engineering (DPHE) at Chapai Nawabganj in late 1993 following reports of extensive contamination of water supplies in the adjoining areas of India.

Based on a study conducted by the British Geological Survey in 1999, there is clearly a very serious problem of arsenic in groundwater in much of southern and eastern

Bangladesh (BGS, 1999). In terms of the population exposed it is the most serious groundwater arsenic problem in the world.

3.2.1 Extent and magnitude of the Problem

As of the survey report of arsenic affected districts, up to February 1997, about 79 villages of 25 districts were affected and about 16 million population is at risk (Khan, 1997). Till March 1997, out of 1487 samples tested from 37 districts 477 samples have shown concentrations above 0.05 mg/L, and 243 samples were in the range of 0.01-0.05 mg/L (Quadiruzzaman, 1997).

3.2.2 Probable Causes of Contamination

Based on the study conducted by the British Geological Survey, the groundwater arsenic problem in Bangladesh is because of an unfortunate combination of three factors- source of arsenic in aquifer sediments, mobilisation- arsenic being released from the sediments to the groundwater through oxyhydroxide reduction, and transport of arsenic within the aquifers.

4.0 The Study Area

4.1 Jhhapa District

4.1.1 General Information

Jhhapa district lies in Mechi zone of the Eastern Development Region of Nepal. It shares its borders with Morang district to the west, Ilam to the north, Bihar state if India to south, and West Bengal state of India to the east. Jhhapa is located between 26^0 20' to 26^0 50' north latitude and 87^0 39' to 88^0 12' east longitude. There are 47 village development committees and 3 municipalities in this district. The district headquarter is Bhadrapur. Elevation in this district ranges from 64 meters to 380 meters above mean sea level (DWSO, 1997a). As of the 1991 census, total population of the district is 593,737. Approximate area of the district is 1606 square kilometers.

4.1.2 Topography and Geology

Nine VDCs of this district- Bahundangi, Shantinagar, Budhabare, Khudunabari, Satasidham, Dharampur, Topgachhi, Lakhanpur, and part of Damak municipality lie in the Terai adjacent to the hilly area of the district. They are generally terraced with flat to medium slopes. Other remaining VDCs lie in the Terai plane and constitute the northern part of the Indo-Gangetic basin that extends from the foot of Churia range to the Indian border. The soil in the hilly area is mainly ordinary gravel, mixed and coarser deposits like boulder, cobble, and gravel exist in the northern part. The terai plain is composed of alluvial deposits of pleistocene to recent in age. The area in the foothill is covered with forest. Most of the part in this district is flat and has gentle slope towards south. The average north-south width is 29 kilometers and length (east-west) is 46 kilometers. Main vegetation in this district is sal, sisaun, champ, teak, chilaune, and etc.

Major perennial rivers of the district are Mechi, Teemai, Ninda, Biring, Kankai, Ratuwa, and Mawa. Rivers of this district together with their origin, destination, and use are shown in the following Table 4.1.

Table 4.1: Major Rivers- Jhhapa District

River	Origin	Destination	Use
Kankai	North of Ilam	To India through Mahavara VDC	Irrigation
Mechi	Sighalila Hills	To India through east of Kechana VDC	Irrigation
Biring	North of Ilam	To India through east of Kumarkhod VDC	Irrigation and WS
Ratuwa	Milkul Hills	To India through west of Khajurgachhi VDC	Irrigation
Mawa	Churia of Jhhapa	Meets with Ratuwa in south of Damak	Irrigation
Hadia	-	-	Irrigation
Ninda/Teemai	-	-	Irrigation and WS
Anduwa	-	-	Irrigation
Devaniya	-	-	Irrigation
Satasi	-	-	Irrigation and WS
Jhharna	-	-	Irrigation and WS
Kamal	-	-	Irrigation

Source: District Profile, DWSO- Jhhapa

4.1.3 Climate

The climate is basically sub-tropical type where pre-monsoon and post-monsoon climate is prevalent. The average temperature fluctuation is between 10 ^{0}C to 35 ^{0}C. The area receives about 80 percent of rainfall during monsoon and pre-monsoon (June-September) and rest during winter. As per the meteorological data recorded in Bhadrapur station the range of annual precipitation is from 930 mm to 2290 mm.

4.1.4 General Health Status

Public health is generally characterized by poor nutrition, lack of safe drinking water and sanitation, and low level of awareness. Total number of patients in the district is recorded to be 110,488 for the FY 98/99. Major disease prevailing in the district is skin disease. Top five diseases as reported by DPHO- Jhhapa for the FY 98/99 is shown in Table 4.2 and they are basically concentrated in the southern part of the district.

Table 4.2: Top-5 Diseases in Jhhapa

S. No.	Diseases	No. Reported	S. No.	Diseases	No. Reported
1.	Skin Disease	12709	4.	ARI	3026
2.	Diarrheal	5423	5.	Pyrexia of unknown origin	2820
3.	Intestinal Worms	5057			

Source: DPHO, Jhhapa

At present, there are altogether 49 government-managed health institutions in the district and they consist of 1 zonal hospital, 8 health service centers, some health posts and 1 homeopathic dispensary. In private sector, there is 1 nursing home, 1 technical institute, and number of health clinics. These institutions are supposed to provide both preventive as well as curative services to the general public.

4.2 Morang District

4.2.1 General Information

Morang district lies in Koshi Zone of the Eastern Development Region of Nepal. This district lies between 26^0 to 26^0 53' north latitude and 87^0 6' to 87^0 42' east longitude. This district has 65 village development committees and one municipality (Biratnagar). Eight of the VDCs lie in hill, three in inner terai, and the remaining fifty-four lie in terai plains. Biratnagar is also known to be the largest industrial estate in the country. The district stretches from hills on northern side to plain terai on south. This district is bordered in north by Dhankuta and Panchthar districts, in east by Jhhapa district, to south by the Bihar State of India, and to the west by Sunsari district. Approximate north-south distance is about 54 kilometers and east-west about 46 kilometers. The district ranges between 150 meters to 2440 meters above mean sea level. As of the 1991 census, total population of the district is 674,823. Approximate area of the district is 1855 square kilometers.

4.2.2 Topography and Geology

Mahabharat range lies in north, Bhabar in inner hills, and plain terai in south. Shale, sandstone, limestone, and metamorphic rocks are the common rocks in the hills of Morang. The Bhabar zone is 8 to 12 kilometers in width and mainly consists of sand and boulders. The land coverage of this district is as follows: 54.7 % by agricultural area, 11.46 % by forest, 4.15 % by pasture, 3.1 % is barren, and the remaining 26.6 % is covered by rivers, banks, road and canals.

Major perennial rivers of this district are as follows:

Ratuwa- This river originates at north-east part of Mahabharat range and later flows as a border for Morang and Jhhapa district and finally enters to India.

Bakraha- This river originates from Mikunji hills and later flows to south.

Lohandra- After mixing with other rivers namely Chisang, Muwa, and Ratuwa this river again gets branched into many smaller ones mainly Chisang and Lohandra.

Singiya- This river originates in Singadevi Sombare VDC at the north west border of the district and flows towards south.

Budhi- This river originates from north west location of Mahabharat range. From Morang, this river enters into Sunsari district and later flows to India.

Besides, Khar Khola, Mawa, Teli, Chancha, Lawa Khola, and Khedam are also rivers of importance in this district.

About 80 % of the district area is plain terai. Groundwater exploitation both at shallow and deep depth is more common in this area. As sub-surface formation is composed of soft soil and sand, tube wells both at shallow and deep depths are more used. As big river and *kholsas* with extended width are flowing here groundwater is naturally recharged in a continuous manner thus facilitating availability of groundwater at shallow depths. Mainly, high concentration of iron is a water quality problem in this area. In inner hills, where water table is deep and the sub-surface formations are usually rocky, dug wells are more commonly used for both irrigation and drinking purposes (DWSO, 1997b).

4.2.3 Climate

Climate of this district is varying type, from sub-tropical to temperate. Average maximum and minimum temperature of the district varies from 30.6 ^{0}C to 14.2 ^{0}C. Annual average rainfall as recorded in Biratnagar station is about 1312.8 mm. Most of the rainfall occurs during the summer monsoon season. Winter temperatures are mild.

4.2.4 General Health Status

There is a good health service infrastructure in this district. Apart from health posts and sub-health posts in villages quite a few nursing homes and private medical dispensaries are also available there. Koshi Zonal Hospital which has an wide array of services and facilities is also located in Biratnagar.

Although no concrete data have been available regarding the number of patients suffering from different diseases, skin diseases and gastro-intestinal diseases are reported to be more frequent. Because of open border to the south many of the people from bordering VDCs are found visiting the medical facilities situated in the adjacent Indian towns across the border.

4.3 Sunsari District

4.3.1 General Information

Sunsari district also lies in Koshi zone of the Eastern Development Region of Nepal. It is located between 26^0 23' to 26^0 55' north latitude and 87^0 5' to 87^0 16' east longitude. As of the 1991 census, total population of the district is 463,481. Approximate area of the district is 1257 square kilometers. The district ranges in elevation between 152 to 914 meters above the mean sea level. There are 49 village development committees and 3 municipalities (Ineruwa, Dharan, and Itahari) in this district. Barahachhetra, Bishnupaduka, and Panchakanya VDCs lie adjacent to the hilly and Bhavar region.

4.3.2 Topography and Geology

Basically, there are three different regions topographically- northern hilly region, Bhavar in mid-land, and southern plain. Bhavar area mainly consists of sand, gravel, and boulders. Southern plain is mainly formed of soft soil and alluvial fertile sediments. Shale, sandy clay, lime, slate stone and other rocks are more common in the hills.

Main River of this district is Saptakoshi. Saptakoshi is the largest river of Nepal and is a mix of the large perennial rivers such as Arun, Sunkoshi, Tamakoshi, Likhu, Indrabati, Tamor, and Dudhkoshi. Besides, other rivers of importance in the district are Budhi khola, Pikhuwa khola, Sarada khola, Tengraha, and Sewati (DDC, 1995).

4.3.3 Climate

Climate of this district is also not very different from that of Morang. Average maximum and minimum temperature of the district varies with the trend presented for Morang earlier. As there is no meteorological station in this district, most of the meteorological data have to be taken as that for Morang. Most of the rainfall occurs during the summer monsoon season and winter temperatures are mild.

4.3.4 General Health Status

Although no concrete data have been available regarding the number of patients suffering from different diseases, skin diseases and gastro-intestinal diseases are reported to be more frequent. Because of open border to the south many of the people from bordering VDCs are found visiting the medical facilities situated in the adjacent Indian towns across the border.

There is a good network of health posts and sub-health posts in villages. Furthermore, there is also one district hospital and various private dispensaries functioning in the district headquarter.

4.4 Groundwater Dependency and Coverage

4.4.1 Dependency

As these districts lie in terai, a large portion of the population depends on the use of groundwater for the drinking purpose. Information related to the dependency of population for groundwater use in Jhhapa, Morang, and Sunsari districts based on 1991-population census is compiled in Table 4.3.

Table 4.3: Population Dependency on Groundwater

Districts	Total Population	Population Dependent on Groundwater	Percentage of Population Dependent on Groundwater
Jhhapa	593,737	558,237	94 %
Morang	674,823	606,565	90 %
Sunsari	463,481	441,806	95 %

Source: CBS, 1991; CBS, 1994; Respective DWSOs

Population projection for groundwater use taking 1998 as Base Year is shown in Table 4.4.

Table 4.4: Population Projection for Groundwater Dependency

Districts	Total Population as per 1991 Census	Population Growth Rate per annum	Total Projected Population for 1998	Total Projected Population Dependent on Groundwater for 1998
Jhhapa	593,737	2.13 %	688,125	646,982
Morang	674,823	2.33 %	792,886	712,686
Sunsari	463,481	2.96 %	568,475	541,890

4.4.2 Coverage

Apart from the DWSOs as lead sectoral agency in implementing water and sanitation projects in these districts a large number of other actors are also found involved in providing drinking water tubewells. DDCs, VDCs, Red Cross, and others are some of those agencies that are involved in this field.

Besides, there are still other sources of support and funding, details for which is hard to find. Furthermore, few users have also installed their own private tubewells. As such, hand pump coverage for Jhhapa, Morang, and Sunsari districts under support from DWSOs getting assistance also from UNICEF and ADB are listed in Tables 4.5, 4.6, and 4.7 respectively.

Table 4.5: Inventory of Tube Wells for Jhhapa District

S. No.	Location (VDC / Municipality)	Total No.	S. No.	Location (VDC / Municipality)	Total No.
1.	Kechana	78	27.	Rajgadh	219
2.	Baniyani	132	28.	Chakchaki	275
3.	Pathamari	87	29.	Ghailadubba	117
4.	Prithvinagar	19	30.	Dangibari	47
5.	Pathariya	191	31.	Charpane	51
6.	Balubari	98	32.	Tangandubba	128
7.	Jalthal	141	33.	Surunga	78
8.	Goldhap	171	34.	Saranamati	161
9.	Bhadrapur NP	108	35.	Kumarkhod	154
10.	Haldibari	37	36.	Dharampur	167
11.	Maheshpur	98	37.	Satasidham	207
12.	Anarmani	-	38.	Shivganj	195
13.	Garamuni	145	39.	Panchgachhi	97
14.	Sanischare	-	40.	Mahabhara	86
15.	Arjundhara	-	41.	Baigundhara	53
16.	Shantinagar	11	42.	Topgachhi	50
17.	Budhabare	-	43.	Korobari	95
18.	Khudunabari	-	44.	Kohabara	174
19.	Dhulabari	29	45.	Gauriganj	45
20.	Dhaijan	113	46.	Khajurgachhi	105
21.	Duwagadhi	77	47.	Maharanijhoda	150
22.	Chandragadhi	12	48.	Jurapani	48
23.	Bahundangi	5	49.	Gauradaha	38
24.	Jyamirgadhi	111	50.	Lakhanpur	192
25.	Kakarvitta	46	51.	Damak NP	17
26.	Gherabari	94	Total		4752

Table 4.6: Inventory of Tube Wells for Morang District

S. No.	Location (VDC / Municipality)	Total No.	S. No.	Location (VDC / Municipality)	Total No.
1.	Belbari	228	23.	Jhhorahat	5
2.	Bayerban	4	24.	Sijuwa	104
3.	Mirgauliya	1	25.	Mahadeva	58
4.	Darbesha	4	26.	Takuwa	79
5.	Hoklabari	128	27.	Mirgauliya	97
6.	Banigama	15	28.	Bayerban	90
7.	Kaseni	15	29.	Motipur	76
8.	Dangraha	15	30.	Jhhurkia	130
9.	Amardaha	80	31.	Sorabhag	135
10.	Hasandaha	15	32.	Bahuni	206
11.	Haraicha	15	33.	Dulari	21
12.	Sundarpur	15	34.	Bhalaha	129
13.	Majhare	129	35.	Tankisinuwari	129
14.	Sanischare	15	36.	Siswani Badahara	67
15.	Jhhorahat	7	37.	Ithara	139
16.	Banigama	7	38.	Bardanga	141
17.	Amahibariyati	100	39.	Dagihaat	72
18.	Kadmaha	12	40.	Indrapur	220
19.	Babiyabirta	102	41.	Kaseni	137
20.	Dadarbairiya	13	42.	Keraun	236
21.	Budhhanagar	91	43.	Lakhantari	84
22.	Baijnathpur	36		Total	3402

Table 4.7: Inventory of Tube Wells for Sunsari District

S. No.	Location (VDC / Municipality)	Total No.	S. No.	Location (VDC / Municipality)	Total No.
1.	Amaduwa	71	24.	Amahibelaha	9
2.	Sahebganj	36	25.	Bhadgaun Sinwari	96
3.	Sripurjabdi	58	26.	Kaptanganj	90
4.	Pakali	61	27.	Jalpapur	100
5.	Basantpur	69	28.	Rajganj Sinuwari	137
6.	Akambha	71	29.	Dumraha	247
7.	Narsingh	116	30.	Satterjhhoda	154
8.	Madheli	97	31.	Madhuban	129
9.	Madhe Harsahi	87	32.	Chandbela	90
10.	Rajganj Belgachhiya	65	33.	Gautampur	60
11.	Devanganj	74	34.	Bharaul	59
12.	Bokraha	195	35.	Baklauri	54
13.	Aurawani	122	36.	Chimri	59
14.	Prakashpur	202	37.	Madhesa	1
15.	Harinagar	104	38.	Paschim Kusaha	81
16.	Lauki	49	39.	Mahendranagar	83
17.	Ghuski	143	40.	Hansposa	84
18.	Ramnagar Bhutaha	153	41.	Duhabi	90
19.	Sonapur	92	42.	Haripur	58
20.	Chhitaha	118	43.	Khanar	58
21.	Madhesa	90	44.	Tanmuna	85
22.	Babiya	52	45.	Singhiya	131
23.	Purba Kusaha	111	46.	Simariya	64
		Total			**4255**

Inventory of deep well pumping schemes under operation through DWSS and NWSC, shallow tube wells, deep-set tubewells, and dug wells functioning in the districts as per the data obtained for the end of FY 1997/98 is presented in Table 4.8.

Table 4.8: Inventory of Wells under Operation

Districts	Deep-well pumping schemes	Shallow and Deepset Tube-wells	Dug-wells
Jhhapa	7	4752	160
Morang	4	3402	NA
Sunsari	3	4255	5

Source: DWSS, DWSOs

Coverage of population dependent on groundwater with completed water supply schemes (groundwater) till the end of FY 1997/98 is shown in Table 4.9. This coverage basically incorporates various projects (deep well pumping, shallow tube wells, deep-set tubewells, and dug wells) completed in districts through DWSS and NWSC. Table 4.9, however, does not include schemes completed privately by the users and by other agencies done in a sporadic manner.

Table 4.9: Coverage of Population Dependent on Groundwater

Districts	Population Dependent on Groundwater as of 1998	Coverage till end of FY 1997/98 (%)
Jhhapa	646,982	348,190 (54 %)
Morang	712,686	251,778 (35 %)
Sunsari	541,890	405,667 (75 %)

4.5 Site Selection for Sample-Testing

Based on feedback, suggestions, recommendations from the Steering Committee, opinion of experts from India and Bangladesh, and the scope of testing as agreed in the terms of reference, about hundred samples in each of the districts had to be tested for determination of arsenic. Selection of these representative samples from a bunch of twelve thousand-plus numbers of tube wells is definitely a colossal task. Following considerations were given in determining the sample selection sites:

1. From shallow tube wells located in the bordering areas of Village Development Committees along Nepal-India border of all three districts;
2. From shallow tube wells located in and around the main settlement and bazaar area along the East-West Highway and the foot-hill areas;
3. Samples would be examined of all the deep tube wells commissioned in these districts. These tube wells although less in number serve a large number of population in urban and bazaar areas; and
4. In addition to the above-mentioned criteria (1-3), few sample tests would be conducted for shallow tube wells along the submerged / flooded area relatively of longer duration eastward from River Koshi in Sunsari district.

In this basis, the locations identified are shown in Table 4.10.

Table 4.10: Site-selection for Sample Tests

District	Criteria	VDCs / Locations
Jhhapa	Bordering VDCs	Jyamirgadhi, Maheshpur, Bhadrapur, Prithvinagar, Pathamari, Kechana, Gherabari, saranamati, Mahavara, Kumarkhop, Tanganduwa, Korabari, Gauriganj, Khajurgachhi
	East-West Highway and Foot-hill area	Kakarvitta, Dhulabari, Charali, Birtamode, Surunga, Damak, Jhiljhile, Kerkha, Dudhe, Sanischare, Durgapur
	Deep tube wells	Kakarvitta, Birtamode, Sanischare, Damak, Bhadrapur, Chandragadhi, Prithvinagar
Morang	Bordering VDCs	Mahadeva, Jhhurkia, Bardanga, Dainiya, Aamgachhi, Rangeli, Sorabhag, Amahibariyati, Nocha, Pokhariya, Majhare, Bhatigachh, Buddhanagar, Rani
	East-West Highway and Foot-hill area	Urlabari, Pathari, Kanepokhari, Laxmimarg, Belbari, Indrapur, Salakpur, Sundarpur
	Deep tube wells	Pathari, Biratnagar, Rangeli
Sunsari	Bordering VDCs	Amaduwa, Sahebganj, Kaptanganj, Bhutaha, Basantpur, Ghuski, Narsingh, Lauki, Sripurjabdi, Haripur
	East-West Highway and Foot-hill area	Itahari, Pakali, Tarara, Inerwa, Kusaha, Bhantabari, Jhhumka, Madhesa, Bakraha
	Deep tube wells	Ineruwa, Itahari, Duhabi
	Submerged or flooded area	Bhantabari, Haripur, Sripur

5.0 Result and Findings

In accordance with the site selection criteria for sample testing as mentioned in Section 4.0 of this report, the Study Team collected a total of 92 samples from Jhhapa, 90 from Morang, and 86 number of samples from Sunsari district. Details of the sampled sites and map of the area are shown in Appendices. Before collecting the water samples from the wells, a preliminary assessment was conducted with the aid of NIPSOM field kit for Jhhapa and Morang, and E-Merck kit for Sunsari district. Samples that showed positive for the field-kit tests were taken for detailed laboratory examination. Moreover, samples from the nearby wells from the one that showed positive in the test were also taken for examination. Details of samples that showed positive for the field test for arsenic are also discussed in this section. Samples were tested in Kathmandu in the NESS laboratory using SDDC spectrophotometry method.

The WHO guideline value for arsenic in drinking water is 0.01 mg/L. So far, no national standard for arsenic has been formulated for Nepal. Both India and Bangladesh have established maximum allowable concentration for arsenic in drinking water to be 0.05 mg/L.

5.1 Jhhapa District

5.1.1 Contamination Scenario

Based on the laboratory report, out of a total 92 samples tested in the laboratory arsenic in a range of concentration ≥ 0.005 mg/L was detected in 6 different samples. The details of the arsenic detected wells are shown in Table 5.1.

Table 5.1: Arsenic detected wells- Jhhapa district

Sample No.	Concentration mg/L	Location	Well Type	Age of Well years	Approx. Depth, ft.
J-3	0.012	Kechana-3, Kechana Kawal	RP	10	24
J-9	0.009	Pathamari-4, Kamadbasti	STW	8	40
J-64	0.027	Korobari-1, Tulachar	STW	19	32
J-65	0.011	Korobari-1, Bhalikhop	STW	11	70
J-67	0.01	Korobari-5, Krishnaghat	STW	6	68
J-87	0.007	Topgachhi-4, Kerkha	STW	3	35

RP- Rower Pump, STW- Shallow Tubewell

Out of the 6 samples that showed arsenic only three do have concentrations higher than the limit set by WHO. Else, remaining three samples are less or equal to the WHO guideline of 0.01 mg/L. Those results exceeding WHO guideline are still below India and Bangladesh standard of 0.05 mg/L.

As regards to the depth of wells, it seems that the contamination zone does not follow a particular trend. Depth of wells starting from 24 feet up to a depth of 70 feet shows occurrence of arsenic. Nothing seems fairly correlated with the wells' age.

Analysis of the test samples showed that all 7 DTWs operating in the district are free from arsenic contamination. Sample J-87 standing as exception, all the samples tested along the Highway and foothill area are free from any contamination. Series of samples along the VDCs in the Indian border are showing contamination. A matter of serious concern is that out of 4 samples tested for Korobari VDC 3 of them show contamination at various levels and various depths.

5.1.2 Health Impact

During the field visit, this Team also collected information regarding any negative health impact related to arsenic on villagers from consumption of water in the sampled area. Few persons having symptoms similar to skin lesions and keratosis had been observed. Anyway this case definitely needs further diagnosis and clinical observations for verification. Details of the persons with such symptoms are shown in Appendix.

5.1.3 Correlation with Field-test

NIPSOM Field kit was used to ascertain the area for collection of samples for laboratory examination. Whenever any cases or symptoms similar to ones related to arsenic were reported, water samples were also collected from the wells that were being used by people with such symptoms. The field kit showed 16 positive cases (concentrations larger or equal to 0.02 mg/L) for arsenic in this district. Out of which only 3 samples (J-3, J-9, and J-64) coincided with the laboratory tests. Samples J-7 and J-8 had behaved strongly positive in field test. However, nothing was detected in the laboratory.

5.2 Morang District

5.2.1 Contamination Scenario

Based on the laboratory report, out of a total of 90 samples tested in the laboratory, arsenic in a range of concentration ≥ 0.005 mg/L was detected in 11 different samples. The details of the arsenic detected wells are shown in Table 5.2.

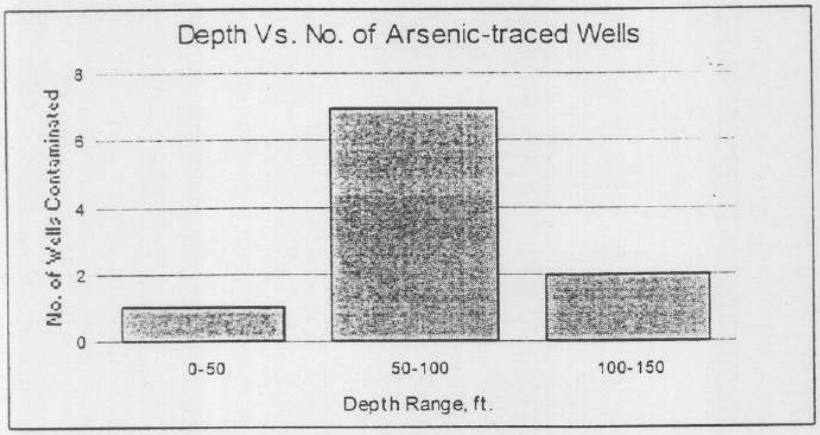
Table 5.2: Arsenic detected wells- Morang District

Sample No.	Concentration mg/L	Location	Well Type	Age of Well years	Approx. Depth, ft.
M-14	0.011	Bardanga-9, Bardanga	STW	5	90
M-21	0.017	Aamgachhi-9, Aamgachhi	STW	7	60
M-28	0.042	DTW Rangeli	DTW	6	300
M-32	0.02	Sorabhag-3, Karsiya West	STW	5	60
M-34	0.05	Sorabhag-4, Simraha	STW	1	65
M-36	0.005	Sorabhag-4, Simraha South	STW	6	132
M-42	0.022	Nocha-1, Nocha	STW	4	65
M-45	0.021	Nocha-3, Nocha	STW	2	70
M-50	0.022	Pokhariya-4, Pokhariya	STW	7	70
M-58	0.019	Bhatigachh-4, Jayarampur	STW	7	115
M-78	0.0077	Kanepokhari-9, Kanepokhari	STW	7	36

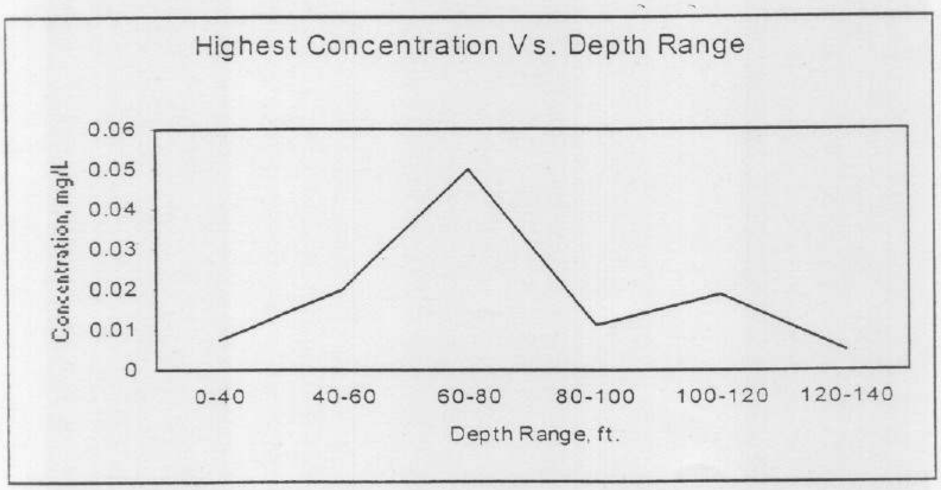
STW- Shallow Tubewell, DTW- Deep Tube Well

Out of the 11 samples that showed arsenic, 9 samples do have concentrations higher than the limit set by WHO. Else, remaining two samples are less or equal to the WHO guideline of 0.01 mg/L. Those results exceeding WHO guideline have not exceeded India and Bangladesh standard of 0.05 mg/L.

As regards to the depth of wells, it seems that the contamination zone basically lies below 60 feet from the ground level. However, well at a depth of 36 feet was found containing some trace arsenic in sample M-78 located in highway foothill area. Nothing seems fairly correlated with the wells' age as it is varying from 1 to a maximum of 7 years. Furthermore, also in this district, series of samples along the VDCs in the Indian border are showing contamination. Dividing the depth matrix in 3 sections falling in range 0-50, 50-100, and 100-150 feet depth and taking DTW as an exception, the number of wells contaminated can be better illustrated from the following chart.



Highest concentration present in the aquifer with respect to varying depth range is seen in the following chart. DTW is taken as exception in this case too.



From the chart above, it seems that the highest concentration range appears in 60-80 feet depth. Concentration of arsenic gradually rises up to 60 – 80 feet range and somehow drops beyond that depth.

At this moment it seems little serious that out of 5 samples taken for laboratory examination from Sorabhag VDC, 3 of them show traces of arsenic. Else, 2 of them have significantly high concentration (0.20-0.50 mg/L) range. Similarly out of 5 samples taken from Nocha VDC, 2 of them are found having concentrations at the range of 0.021-0.022 mg/L range. Furthermore, laboratory analysis has shown that sample from DTW Rangeli

(M-28) has a concentration of 0.042 mg/L of arsenic. Although the concentration is somehow below India and Bangladesh limit, necessary action has to be taken immediately for averting the future arsenic risk.

5.2.2 Health Impact

During the field visit, this Team also collected information regarding any negative health impact related to arsenic on villagers from consumption of water in the sampled area. As the exposure duration is not long enough to create any significant manifestations, serious impact could not be seen readily. However, few persons were found with symptoms similar to arsenicosis. Anyway this case definitely needs further diagnosis and clinical observations for verification. Details of the persons with such symptoms are shown in Appendix.

5.2.3 Correlation with Field-test

NIPSOM Field kit was used to ascertain the area for collection of samples for laboratory examination. Whenever any cases or symptoms similar to ones related to arsenic were reported, water samples were also collected from the wells that were being used by people with such symptoms. The field kit showed 9 positive cases (concentrations larger or equal to 0.02 mg/L) for arsenic in this district. Out of which only 4 samples (M-34, M-42, M-50, and M-58) coincided with the laboratory result.

5.3 Sunsari District

5.3.1 Contamination Scenario

Based on the laboratory report, out of a total of 86 samples tested in the laboratory, arsenic in a range of concentration ≥ 0.005 mg/L was detected in 16 different samples. The details of the arsenic detected wells are shown in Table 5.3.

Table 5.3: Arsenic detected wells- Sunsari district

Sample No.	Concentration mg/L	Location	Well Type	Age of Well years	Approx. Depth, ft.
S-40	0.015	Narsingh-3, Narsingh	STW	4	40
S-51	0.075	Sripurjabdi-4, Sripur	STW	10	25
S-53	0.0063	Sripurjabdi-2, Sripur	STW	10	16
S-55	0.027	Haripur-4, Yadavtole	STW	5	45
S-56	0.019	Haripur-2, Haripur	STW	5	20
S-57	0.011	Haripur-1, haripur	STW	10	16
S-58	0.012	Haripur-8, Bhantabari	STW	5	30
S-59	0.053	Haripur-8, Bhantabari	STW	3	40
S-60	0.017	Haripur-6, Sadepa	STW	8	40
S-61	0.005	Bhantabari	STW	10	36
S-62	0.0057	Bhantabari, Driver Tole	STW	1	15
S-63	0.026	Bhantabari, Southwest	STW	3	20
S-65	0.0063	Sripur-8, Juddhaganj	STW	18	16
S-66	0.012	Kusaha-9, Jamuwanahar	STW	1	20
S-71	0.014	Bakraha-9, Chirauli North	STW	5	25
S-82	0.023	Itahari-2, Sundarpur Line	STW	14	36

STW- Shallow Tubewell

Out of the 16 samples that showed arsenic, 12 samples do have concentrations higher than the limit set by WHO. Else, the remaining four samples are less or equal to the WHO guideline of 0.01 mg/L. Out of those results exceeding WHO guideline, two samples have even exceeded India and Bangladesh standard of 0.05 mg/L.

According to the Table above, all six samples collected in Haripur VDC are showing varying concentrations of arsenic. This is the single VDC in the district for which all the samples showed presence of arsenic in laboratory test. Yet, three more samples (S-61, S-62, S-63) also from Haripur VDC in submerged and flooded area category showed traces of arsenic contamination. All these test sites are very close to River Koshi. It seems that serious attention has to be given to the water quality with regards to arsenic in this particular belt.

One interesting fact here is that all the contaminated wells are within the depth of 45 feet. In this area, because of the seepage from the River Koshi one can naturally get water in a lower depth. As exception one sample (S-82) is found containing arsenic at a concentration of 0.023 mg/L in remote Itahari area along the Highway line. Else, western part of the district along the India border is now seen as the hot pocket for arsenic. Nothing seems fairly correlated with the wells' age as it is varying from 1 to a maximum of 18 years. All 3 DTWs did not show in them any occurrence of arsenic.

5.3.2 Health Impact

During the field visit, this Team also collected information regarding any negative health impact related to arsenic on villagers from consumption of water in the sampled area. As the exposure duration is not long enough to create any significant manifestations, serious impact could not be seen readily. However, very few persons were found with symptoms similar to arsenicosis. Anyway this case definitely needs further diagnosis and clinical observations for verification. Details of the persons with such symptoms are shown in Appendix.

5.3.3 Correlation with Field-test

E-Merck Field kit was used to ascertain the area for collection of samples for laboratory examination. Whenever any cases or symptoms similar to ones related to arsenic were reported, water samples were also collected from the wells that were being used by people with such symptoms. The field kit showed 21 positive cases for arsenic in this district. Out of which only 6 samples (S-40, S-58, S-59, S-63, S-66, and S-71) coincided with the laboratory result.

5.4 Cross-comparison of Sample Test Result

Due to some unavoidable circumstances, it was possible to cross-check only 18 number of samples with AAS-HG method. Comparison of results is shown in Table 5.4.

Table 5.4: Comparison of Result for some Selected Samples

Method	Samples																	
	M-78	S-40	S-53	S-54	S-55	S-56	S-57	S-58	S-59	S-60	S-61	S-62	S-63	S-64	S-65	S-66	S-71	S-82
SDDC	0.0077	0.015	0.0063	ND	0.027	0.019	0.011	0.012	0.053	0.017	0.005	0.0057	0.026	ND	0.0063	0.012	0.014	0.019
AAS-HG	ND	0.009	0.003	ND	0.026	0.028	0.008	0.011	0.044	0.018	0.007	0.006	0.012	0.004	0.005	0.012	ND	0.019

6.0 Conclusion and Recommendations

6.1 General Conclusion

Within the given time frame of six and half months for this study many of the important aspects related to arsenic contamination of groundwater have been studied. Strength and capacity of neighboring country-institutions in addressing this problem have also been studied to some extent. Else, the situation of groundwater contamination with this particular contaminant in the proposed study area (Jhhapa, Morang, and Sunsari districts) has also been analysed and studied. Laboratory-test results for some of the tubewell water samples showed varying degree of concentration of arsenic in the study area. Detailed picture of the extent and magnitude of this situation can be seen only after the in-depth and denser studies in the affected areas.

At this moment, it seems that there are some sporadically located relatively lower concentration pockets of arsenic in Jhhapa and moderate concentration pockets in Morang. In case of Sunsari district, arsenic contamination of groundwater seems localised in the western part of the district very close to River Koshi.

The set objectives have been met in the following manner:

1. Findings of the neighboring country institutions regarding arsenic crisis in this area (West Bengal of India and Bangladesh) have been reviewed;
2. Occurrence and concentration of arsenic sufficient to influence drinking water quality in the study area have been determined;
3. Some cases of negative health effects from consumption of groundwater in the study area have been identified; and
4. Based on findings of the study, some recommendations have been made too.

Some limitations of this study are:

1. This study is not sufficient to fully estimate probable risk, extent, and magnitude of the problem for the study area;
2. This study was conducted during post-monsoon period. Hence, variation in results in other seasons can't be ruled out; and
3. Without a detailed study, the situation of arsenic contamination can't be generalised for areas other than the ones studied here currently.

6.2 Recommendations

6.2.1 General Recommendations

Following recommendations have been made on the basis of experience gained from this study:

1. To get a clear picture of arsenic contamination, area of the present study has to be expanded;
2. Extent and magnitude of the problem together with probable risk has to be estimated;

3. Water quality monitoring has to be done systematically and periodically;
4. So as to avert risk of touching arsenic contaminated aquifers, guidelines have to be established for STW installation in the affected areas;
5. Health effect has to be monitored in detail together with professionals from Department of Health;
6. Work has to be started toward developing national drinking water quality standard for safe concentration limit of arsenic; and
7. Some preventive measures have to be taken immediately for offsetting further exposure of arsenic in tubewells that showed concentration ≥ 0.05 mg/L.

6.2.2 Further Research

This study suggests further research in the following areas:

1. More detailed and denser studies have to be conducted;
2. Seasonal variation of arsenic has to be ascertained;
3. Soil and bore-hole sediment samples have to be tested for arsenic; and
4. Geo-chemical and hydro-geological phenomena have to be studied in detail for ascertaining probable cause of presence of arsenic in groundwater aquifers in Nepal.

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APPENDICES

Appendix - 1

Map of the Study Area

Source: Nepal in Maps. Educational Enterprise Pvt. Ltd., Kathmandu, 1988

Brief Description of the Eastern Development Region

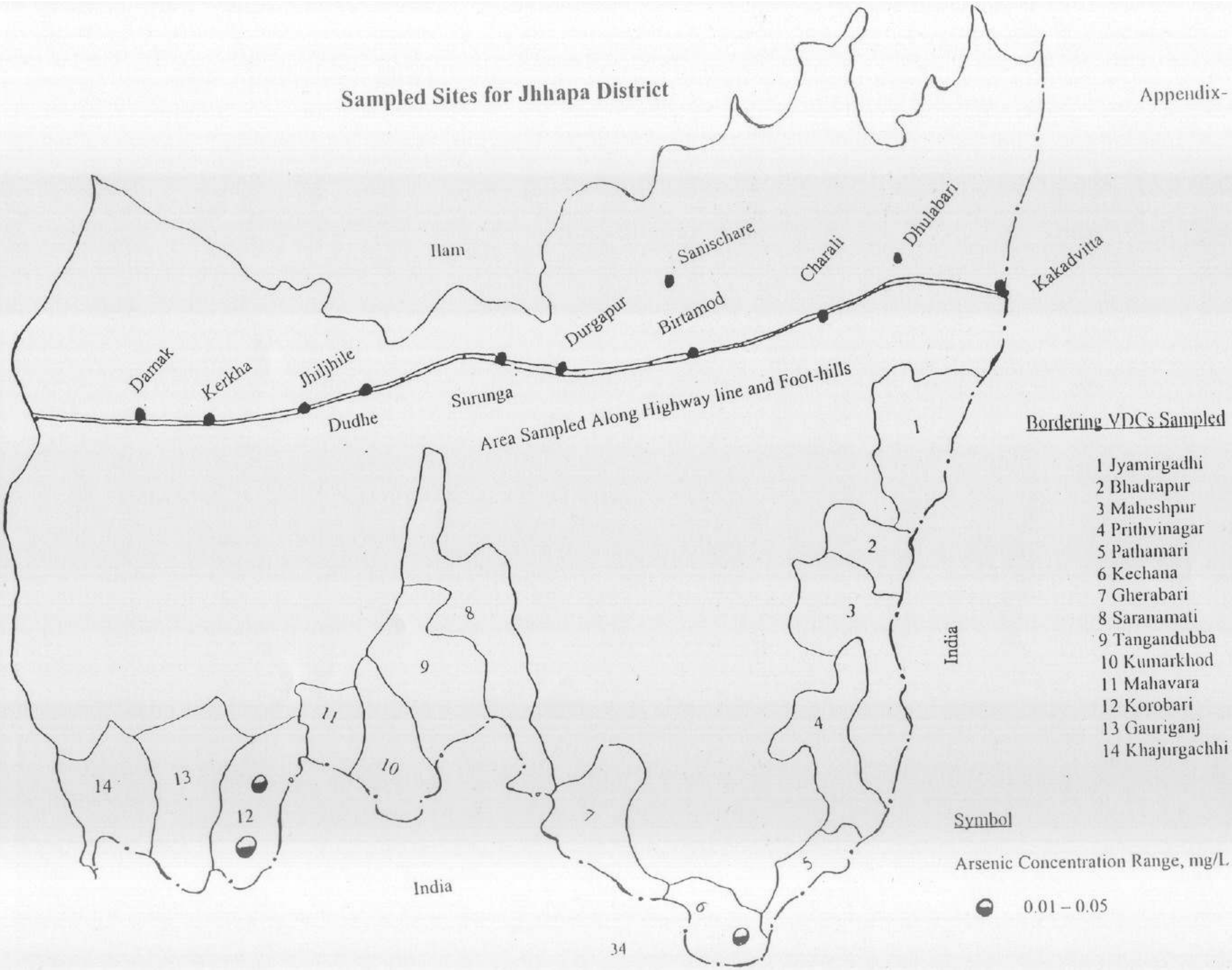
It is located in the extreme eastern part of Nepal. It is the second most developed region. This region shares about 19 % of the total area, and 25 % of the total population of Nepal, ranking third and second positions respectively. Dhankuta is the development centre of the region.

Elevation in the region ranges from the minimum of 61 metres in the southern part of Saptari District to the maximum of 8848 metres above sea level in the northern part of Solukhumbu District.

The narrow terai belt is economically the most developed area of the region. Several snowy peaks and the deepest gorge of the Arun river are its attractive features (Nepal in Maps, 1988).

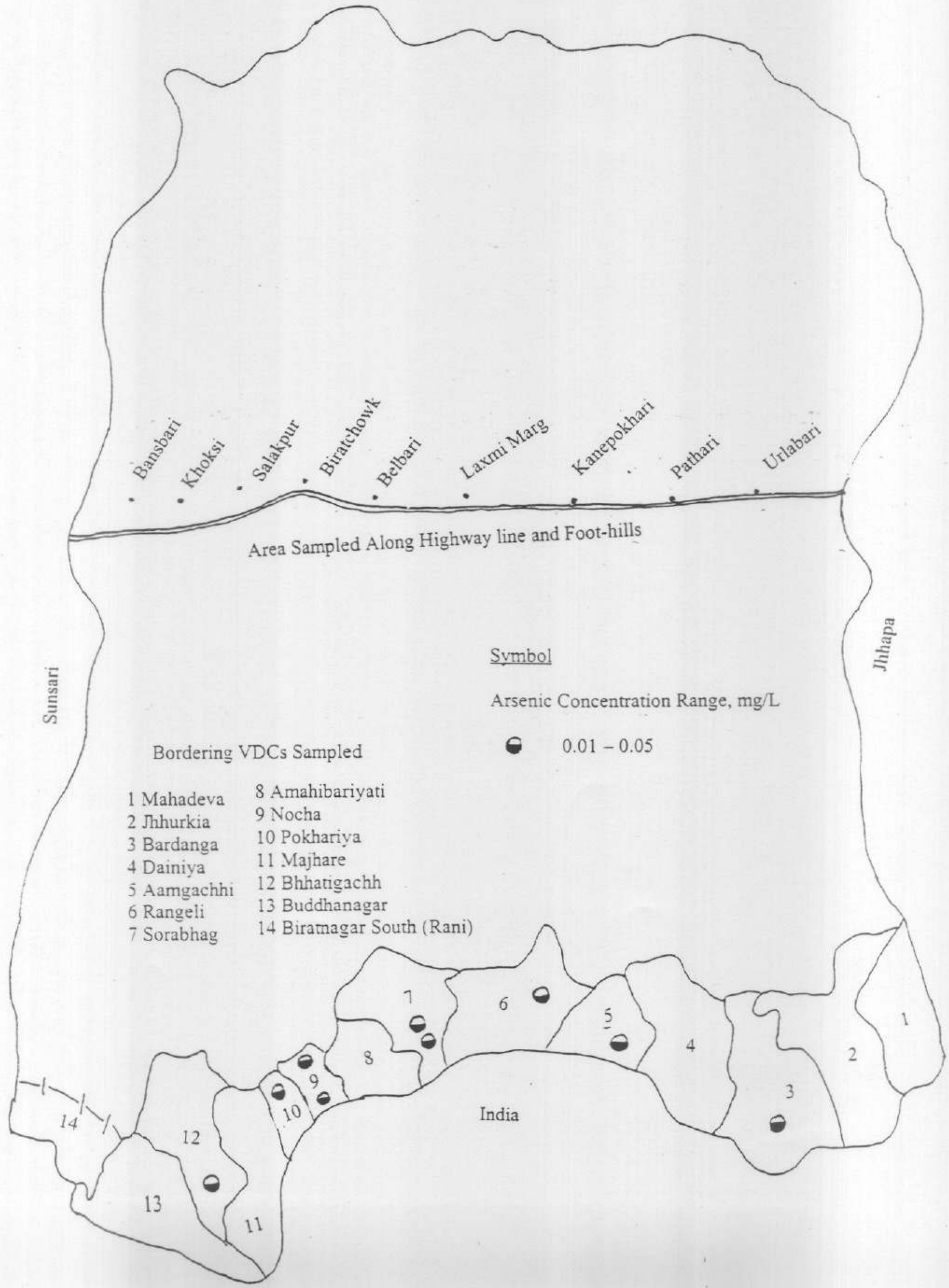
Appendix- 2

Sampled Sites for Jhhapa District



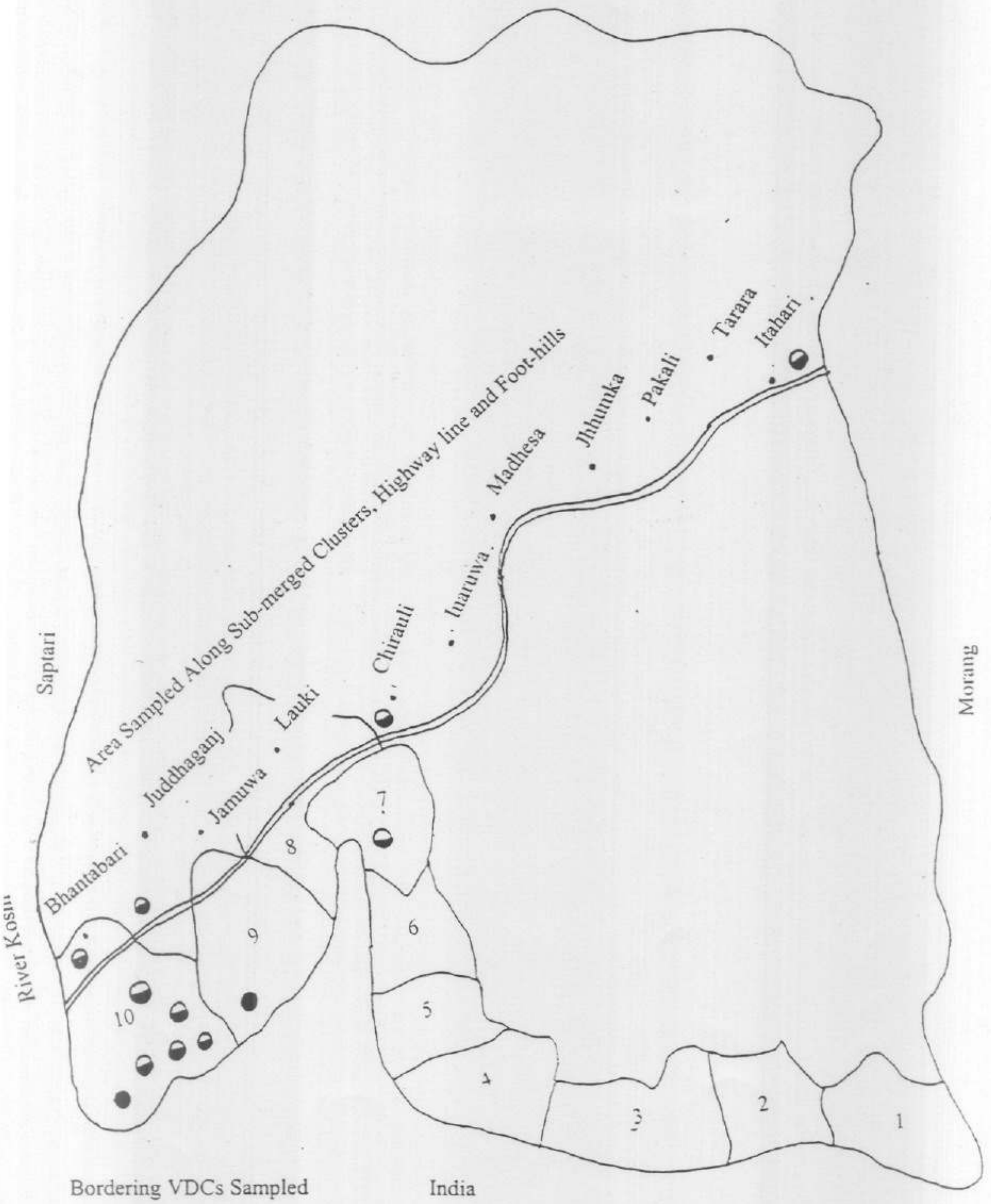
Appendix- 3

Sampled Sites for Morang District



Appendix- 4

Sampled Sites for Sunsari District



Bordering VDCs Sampled

1 Amaduwa
2 Sahebganj
3 Kaptanganj
4 Ghuski
5 Basantpur
6 Ramnagar Bhutaha
7 Narsing
8 Lauki
9 Sripurjabdi
10 Haripur

Symbol

Arsenic Concentration Range, mg/L

◒ 0.01 – 0.05

● > 0.05

Appendix-5: Inventory of Wells for Arsenic Sample-Testing

District: Jhhapa

Ward No.	Location	Date	Sample No.	Well Type	Owner / Household Head Nearby	Age of Well, yrs.	Approx. Depth, ft.	HH served	Health Effects, if any observed at field level
VDC: Kechana									
4	Khuttamani	9/29	J-1	STW	Udit Narayan	12	75	5	
3	Kechana	9/29	J-2	STW	Sorab Miya	12	75	20	
3	Kechana Kawal	9/29	J-3	Rower Pump	Bishnu Pd. Khatiwoda	10	24	2	
1	Kechana	9/29	J-4	STW	Mahabir Lall	5	30	14	
2	Kechana West	9/29	J-5	STW	Ambar Singh	1	50	3	
1	Kechana	9/29	J-6	STW	Om Nath	1	27	1	
9	Chalise Tole	9/29	J-7	Dug Well	Parsuram Adhikari	19	18	2	Some symptoms very similar to arsenic poisoning
9	Chalise Tole	9/29	J-8	STW	Parsuram Adhikari	1	20	2	
VDC: Pathamari									
4	Kamadbasti	9/29	J-9	STW	Bajaree Ganesh	8	40	5	Some symptoms very similar to arsenic poisoning
4	Kamadbasti	9/29	J-10	STW	Paradlal Ganesh	8	40	8	
5	Kilabasti	9/29	J-11	STW	Nengru Miya	8	45	8	
5	Kilabasti	9/29	J-12	STW	Sahbuddin Miya	5	65	8	Some skin pigmentation symptoms
VDC: Prithbinagar									
6	Saubare	9/30	J-13	STW	Habbar Palten	8	70	2	
8	Himali Chowk	9/30	J-14	STW	Pradip Subba	2	60	2	
6	DWSS	9/30	J-15	DTW	DWSO Jhhapa	10	500	NA	
5	Charali Chowk	9/30	J-16	STW	Khemraj Bhandari	11	27	1	
5	Sagarmatha	9/30	J-17	STW	Ser Bdr. Bhattarai	4	55	100	
4	Dhat Salik	9/30	J-18	STW	Tej Bdr. Subba	4	40	1	
VDC: Maheshpur									
3	Surya Nagar	9/30	J-19	STW	Yam Bdr.	7	32	4	
1	Gaine Chowk	9/30	J-20	STW	Khadga Siwakoti	8	75	5	
3	Aanp Gachhi	9/30	J-21	STW	Gunjama	8	90	6	
1	Bansbari	9/30	J-22	STW	NA	1	70	10	
8	Telebhita	9/30	J-23	STW	Bhogaraja	8	65	6	Skin symptoms prevalent
9	Battobari	9/30	J-24	STW	Sushil Rajbansi	8	85	9	

District: **Jhhapa**

Inventory of Wells for Arsenic Sample-Testing, contd.

Ward No.	Location	Date	Sample No.	Well Type	Owner / Household Head Nearby	Age of Well, yrs.	Approx. Depth, ft.	HH served	Health Effects, if any
VDC: Bhadrapur and Municipality									
2	Dharmabh. Path	9/30	J-25	STW	Birani Rajbansi	2	85	10	Some skin manifestations prevalent
3	Ganesh Mandir	9/30	J-26	STW	Raj Kumar Karki	4	60	3	
8	Bhagauri Tole	9/30	J-27	STW	Ravi Kanti	3	65	10	
10	Police Office	10/4	J-28	STW	PO	15	40	NA	
11	Jagriti Nagar	10/4	J-29	STW	Dev Raj Ghimire	9	25	1	
6	Patuwari Tole	10/4	J-30	STW	Ghanasyam Chand	12	30	1	
Along East-West Highway / Foothill area									
3	Birtamod	10/1	J-31	DTW	Birtamod UC	2	250	700	
3	Birtamod	10/1	J-32	STW	Hotel Yangki	4	72	1	
4	Birtamod	10/1	J-33	STW	Jyoti Rana	12	40	NA	
2	Sanischare	10/1	J-34	STW	Mangru	6	26	4	
1	Sanischare	10/1	J-35	STW	Jaleswar Misthan	1	26	4	
2	Sanischare	10/1	J-36	DTW	UC Sanischare	4	220	450	
5	Charali	10/1	J-37	STW	Kalpana Tamang	7	25	8	
5	Charali Telibari	10/1	J-38	Dug Well	Khurkimdu Rajbansi	30	20	10	
1	Dhulabari/south	10/1	J-39	STW	Gyan Pd. Rimal	1	29	5	
1	Dhulabari/East	10/1	J-40	STW	Bhakta Bdr. Karki	1	22	5	
10	Kakarvitta	10/1	J-41	DTW	Kakarvitta UC	4	NA	980	
10	Kakarvitta	10/1	J-42	Dug Well	Dev Kumar Sahi	25	15	Priv.	
11	Kakarvitta	10/1	J-43	STW	Tika Maya Rai	1	10	Priv.	
VDC: Jyamirgadhi									
7	Kanchamukhia	10/1	J-44	STW	Sajan Meche	11	60	5	
7	Kanchamukhia	10/1	J-45	STW	Dharmananda Kandel	2	22	1	
5	Laljhoda	10/1	J-46	STW	Shaivakoti Kirana	2	23	1	
3	Bichari bajar	10/1	J-47	STW	Tara Bdr. Raut	7	28	1	

District: **Jhhapa**

Inventory of Wells for Arsenic Sample-Testing, contd.

Ward No.	Location	Date	Sample No.	Well Type	Owner / Household Head Nearby	Age of Well, yrs.	Approx. Depth, ft.	HH served	Health Effects, if any
VDC: Sharanamati									
6	Chapramari	10/2	J-48	STW	Hari Pd. Silwal	5	40	9	
5	Shanti Chowk	10/2	J-49	STW	Jit Bdr. Rai	5	38	12	
5	Bazar	10/2	J-50	STW	Man Bahadur	3	35	7	
4	Fulgachhi	10/2	J-51	STW	Jibanath Prasai	9	16	1	
VDC: Tangandubba									
1	Kamad Toli	10/2	J-52	STW	Laxmi Upreti	3	38	5	
7	Kamartali	10/2	J-53	STW	Ganesh Rai	2	40	5	
2	Jhapa Bazar	10/2	J-54	STW	Kul Bdr. Shrestha	3	25	1	
3	Zamar	10/2	J-55	STW	Chank Lal Ganesh	10	16	2	
VDC: Kumarkhod									
9	Jhapa Bazar	10/2	J-56	STW	Rewat KC	10	20	1	
9	Jhapa Bazar	10/2	J-57	STW	Jeewan Shrestha	8	20	1	
5	Ku,mar Daha	10/2	J-58	STW	Jita Rajbanshi	1	15	1	
1	Baisha Khu	10/2	J-59	STW	Daya Lal Singh	1	25	3	
VDC: Mahabhara									
1	Mahavarachok	10/3	J-60	STW	Agni	5	34	2	
2	Mahavarachok	10/3	J-61	STW	Ganga Pd. Gautam	1	21	1	
3	Kunji Bari	10/3	J-62	STW	Laxman Rajbansi	9	70	7	
4	Kunji Bari	10/3	J-63	STW	Magal Rajbansi	3	25	5	
VDC: Korobari									
1	Tulachar	10/3	J-64	STW	Hari Bdr. Niraula	19	32	5	
1	BhaluKhop	10/3	J-65	STW	Tika Raj Chaulagain	11	70	4	
5	Taturea Mari	10/3	J-66	STW	Bahadur Lal Rai	12	115	6	
5	Krisnaghat	10/3	J-67	STW	Trilochan Giri	6	68	7	
VDC: Gauriganj									
8	Theki Tola	10/3	J-68	STW	Kedar Nath	7	30	3	
7	Gauriganjchok	10/3	J-69	STW	Mahabir Haluwai	12	26	5	

District: Jhhapa

Inventory of Wells for Arsenic Sample-Testing, contd.

Ward No.	Location	Date	Sample No.	Well Type	Owner / Household Head Nearby	Age of Well, yrs.	Approx. Depth, ft.	HH served	Health Effects, if any
VDC: Gauriganj contd.									
5	Maharajthan	10/3	J-70	STW	Devi Bhakta Subba	7	20	2	
6	Kripal Tole	10/3	J-71	STW	Sajan Raj	5	25	1	
VDC: Khajurgachhi									
6	Khajurbazar	10/3	J-72	STW	Ganga Piya	8	18	3	
6	Bhaisen Tole	10/3	J-73	STW	Hari Baraili	4	25	1	
5	Atha Maiya	10/3	J-74	STW	Gadu Miya	8	17	7	
8	Govindraj Tole	10/3	J-75	STW	Govind Bista	5	23	2	
15	Bhadrapur	10/4	J-76	DTW	DWSO				
VDC: Chandragadhi									
8	Lekhanathchok	10/4	J-77	STW	Tulashi Dhakal	10	45	7	
7	Lekhanathchok	10/4	J-78	STW	Kul Raj	5	35	4	
VDC: Ghailadubba									
1	Durgapur	10/5	J-79	STW	Gyan Bdr.	8	30	4	
1	Durgapur	10/5	J-80	STW	Kailu Sahu	3	28	1	
VDC: Surunga									
5	Surunga	10/5	J-81	STW	Vikram Rajbansi	2	16	1	
5	Surunga	10/5	J-82	STW	Aathrai Hotel	5	16	1	
VDC: Satasidham									
6	Dudhe	10/5	J-83	STW	Hotel Staff	5	40	3	
7	Dudhe	10/5	J-84	STW	Hotel Shrestha	4	22	7	
5	Jhiljhile	10/5	J-85	STW	Amar Lama	18	32	1	
9	Jhiljhile	10/5	J-86	STW	Khadga Bdr. Thapa	2	22	1	
VDC: Topgachchi									
4	Kerkha	10/5	J-87	STW	Chandra Bdr. Thebe	3	35	1	
7	Kerkha	10/5	J-88	STW	Tek Bdr. Khadka	10	30	1	
Damak NP									
1	DTW Damak	10/5	J-89	DTW	UC	6	250		
11	Damak	10/5	J-90	STW	Man Bdr. Budhathoki	2	16	7	
13	Highwayline	10/5	J-91	STW	Dilip Bdr.	12	30	1	
	Chandragadhi	10/6	J-92	DTW	DWSO				

Appendix- 6: Inventory of Wells for Arsenic Sample-Testing

District: **Morang**

Ward No.	Location	Date	Sample No.	Well Type	Owner / Household Head Nearby	Age of Well, yrs.	Approx. Depth, ft.	HH served	Health Effects, if any observed at field level
VDC: Mahadeva									
1	Hatkhola	11/19	M-1	STW	Nagina Yadav	12	117	10	
3	Chaukighat	11/19	M-2	STW	Doman lal Singh	4	26	3	
2	Chaukighat	11/19	M-3	STW	Bachchu Gaugai	2	26	3	
3	Baluwatar	11/19	M-4	Dug Well	Public	3	60	10	
2	Baluwatar	11/19	M-5	STW	Phata Sharma	5	30	2	
VDC: Jhhurkia									
9	Bhadra Chowk	11/19	M-6	STW	Sukdev Sah	1	32	3	
9	Bhadra Chowk	11/19	M-7	STW	Padam Bista	1	36	3	
7	Bhadra Chowk	11/19	M-8	STW	Prasain	3	36	4	
8	Sijuwa-8	11/19	M-9	STW	Bhagiman Kandangwa	7	80	4	
7	Payamari	11/19	M-10	STW	Baigun Lal Taj	7	80	5	
VDC: Bardanga									
9	Keurat	11/20	M-11	STW	Jadlal Das	1	25	5	
9	Bardanga	11/20	M-12	STW	Kumar Chand	12	145	12	
3	Kureli	11/20	M-13	STW	Feroze	2	26	6	
9	Bardanga	11/20	M-14	STW	Manbir Das	5	90	6	
6	Kureli	11/20	M-15	STW	Surendra Rajbansi	1	63	6	
VDC: Dainiya									
4	Karenja	11/20	M-16	STW	Anant Lal Sah	2	45	1	
8	Bazar East	11/20	M-17	STW	Purna Rai	8	16	5	
8	Labtoli	11/20	M-18	STW	Rameswar Risideo	3	38	10	
8	Bazar	11/20	M-19	STW	Suhan Lal Singh	12	36	1	
3	Harischadgadh	11/20	M-20	STW	Kapur Ch. Rajbansi	3	35	1	
VDC: Aamgachhi									
9	Aamgachhi	11/20	M-21	STW	Rameswar Mandal	7	60	4	
4	Aamgachhi	11/20	M-22	STW	Rambilas Sundar	6	30	5	
1	Aamgachhi	11/20	M-23	STW	Uttamlal Mandal	8	104	5	
4	Aamgachhi	11/20	M-24	STW	Satish Ch. Mandal	4	103	5	
3	Kadamgachhi	11/20	M-25	STW	Dukhai Mahato	2	105	5	

Inventory of Wells for Arsenic Sample-Testing, contd.

District: Morang

Ward No.	Location	Date	Sample No.	Well Type	Owner / Household Head Nearby	Age of Well, yrs.	Approx. Depth, ft.	HH served	Health Effects, if any observed at field level
VDC: Rangeli									
5	Rangeli East	11/20	M-26	STW	Nageswar Mandal	20	25	4	
4	Tetri Tole	11/20	M-27	STW	Madan Agrawal	10	15	3	
	DTW Rangeli	11/20	M-28	DTW	UC	6			
4	Rangeli North	11/20	M-29	STW	Min Bdr. Ghimire	7	18	4	
2	Rangeli South	11/20	M-30	STW	Ramanand Yadav	4	20	3	
2	Rangeli South	11/20	M-31	STW	Mahavir Yadav	30	16	6	
VDC: Sorabhag									
3	Karsiya West	11/21	M-32	STW	Hemant Autom.	5	60	Public	
3	BP Chowk S.	11/21	M-33	STW	Dasmi Rajbansi	6	130	Public	
4	Simraha	11/21	M-34	STW	Ganesh Rajak	1	65	5	
4	Simraha South	11/21	M-35	STW	Mohanraj Pande	7	70	50	
4	Simraha South	11/21	M-36	STW	Ludaru Mandal	6	132	7	
VDC: Amahibariyati									
1	Bariyati	11/21	M-37	STW	Jarban Mandal	10	155	10	
2	Bariyati	11/21	M-38	STW	Balaram Mandal	10	155	11	
2	Bariyati West	11/21	M-39	STW	Bhimlal Paswan	10	175	6	
2	Bariyati SE	11/21	M-40	STW	Rajnanda Katuwal	2	100	1	
4	Amahi	11/21	M-41	STW	Kali Pd. Paswan	10	140	5	
VDC: Nocha									
1	Nocha	11/21	M-42	STW	Durga School	4	65	5	
2	Nocha	11/21	M-43	STW	Bandhulal Mandal	4	50	5	
2	Nocha	11/21	M-44	STW	Rukumlal Chaudhry	2	16	2	
3	Nocha	11/21	M-45	STW	Lalchandra Mandal	2	70	7	
4	Nocha	11/21	M-46	STW	Bel Bhadra	5	42	5	
VDC: Pokhariya									
6	Theki Tole	11/21	M-47	STW	Mohammad Samsul	1	40	3	
6	Pokhariya	11/21	M-48	STW	Ibrahim Ansari	7	160	5	
5	Pokhariya	11/21	M-49	STW	Bimalu Mandal	7	90	20	
4	Pokhariya	11/21	M-50	STW	Beju Mandal	7	70	15	
4	Pokhariya	11/21	M-51	STW	Bilash Rishideo	1	30	4	

Inventory of Wells for Arsenic Sample-Testing, contd.

District: **Morang**

Ward No.	Location	Date	Sample No.	Well Type	Owner / Household Head Nearby	Age of Well, yrs.	Approx. Depth, ft.	HH served	Health Effects, if any observed at field level
VDC: Bhatigachh									
3	Mandir	11/22	M-52	STW	Radhekrishna Mandir	3	35	10	
4	Jayarampur	11/22	M-58	STW	Raj Bdr. Rajbansi	7	115	10	
2	Baban Toli	11/22	M-59	STW	Abdes Kumar Misra	7	50	10	
7	Hatibandh	11/22	M-60	STW	Ghinnulal Rajbansi	2	45	2	
2	Baban Toli	11/22	M-61	STW	Alkhu Rajbansi	7	45	6	
VDC: Majhhare									
3	Laxmaniyahat	11/22	M-53	STW	Rambilash Singh	7	75	4	
3	Laxmaniyahat	11/22	M-54	STW	Police Unit	8	195	10	
4	Majhare	11/22	M-55	STW	Khelananda Mahato	5	45	5	
7	Sirsiya	11/22	M-56	STW	Ram Khilam Sahu	15	41	4	
2	Majhare	11/22	M-57	STW	Kokan Mahato	8	35	2	
VDC: Buddhanagar									
7	Buddhanagar	11/22	M-62	STW	Ashok Rajbansi	5	35	2	
2	Buddhanagar	11/22	M-63	STW	Ram Bilas Master	1	55	2	
1	Jhatiyahi	11/22	M-64	STW	Shiv Sankar Kewat	2	51	10	
1	Jhatiyahi	11/22	M-65	STW	Mungilal Das	7	80	7	
1	Naya Tole	11/22	M-66	STW	Ram Kewal Das	15	45	5	
Biratnagar Sub-Metropolitan City									
22	Rani Mills	11/22	M-67	STW	Sambhu Sah	1	45		
21	Manthapokhri	11/22	M-68	STW	Babaji Sriram Giri	2	45		
22	Line Quarter	11/22	M-69	STW	Lekh Bdr. Ghimire	1	45		
21	Rani	11/22	M-70	STW	Mohan Lal Mandal	NA	40		
19	Rani	11/22	M-71	STW	Amar Bdr. Basnet	12	40		
21	DTW Rani	11/22	M-72	DTW	DTW / NWSC				

District: **Morang**

Inventory of Wells for Arsenic Sample-Testing, contd.

Ward No.	Location	Date	Sample No.	Well Type	Owner / Household Head Nearby	Age of Well, yrs.	Approx. Depth, ft.	HH served	Health Effects, if any observed at field level
Along Highway and Foothill Area									
VDC: Urlabari									
3	Hatkhola	12/4	M-73	STW	Bhim Bahadur Rai	10	17		
2	Chowk North	12/4	M-74	STW	Hari Maya	1	25		
	DTW Pathari	12/4	M-75	DTW	DWSO/UC	1	450		
VDC: Pathari									
1	Pathari South	12/4	M-76	STW	Bhim Bahadur	2	25		
1	North	12/4	M-77	STW	Savitra Neupane	6	24		
VDC: Kanepokhari									
9	Kanepokhari	12/4	M-78	STW	Kuber Thapa	7	36		
9	Bayerban	12/4	M-79	STW	Ganga Deuja	6	60		
VDC: Dangihaat									
5	Laxmimarg	12/4	M-80	STW	Govind Limbu	1	22		
5	South	12/4	M-81	STW	Homnath Niraula	3	26		
VDC: Belbari									
2	Belbari	12/4	M-82	STW	Naramaya Rai	2	24		
2	North	12/4	M-83	STW	Bhim Bdr. Khatri	15	20		
VDC: Indrapur									
4	Biratchowk	12/4	M-84	STW	Tirtha Bdr. Thapa	7	26		
3	North	12/4	M-85	STW	Govind Karki	4	35		
VDC: Mirgauliya									
9	Salakpur	12/4	M-86	STW	Sarad Adhikari	9	30		
9	North	12/4	M-87	STW	KhemRaj Pokhrel	3	26		
VDC: Sundarpur									
8	Khoksi	12/4	M-88	STW	Satyanarayan Peskar	10	36		
8	Banshari	12/4	M-89	STW	Krishnamaya Khadka	5	55		
	DTW	12/4	M-90	DTW	NWSC/Biratnagar				

Appendix- 7: Inventory of Wells for Arsenic Sample-Testing

District: Sunsari

Ward No.	Location	Date	Sample No.	Well Type	Owner / Household Head Nearby	Age of Well, yrs.	Approx. Depth, ft.	HH served	Health Effects, if any observed at field level
VDC: Amadubba									
4	Bairiya	11/30	S-1	STW	Sukra Rishidev	1	45	6	
4	Bairiya	11/30	S-2	STW	Yemar Lal Chy.	4	45	3	
4	Bairiya	11/30	S-3	STW	Jagdish Gurung	2	28	10	
5	Naragaraha	11/30	S-4	STW	Prithvi Lal Chy.	6	38	6	
5	Naragaraha	11/30	S-5	STW	Mahadev Chaudhari	11	65	15	
7	Hatiya Tole	11/30	S-6	STW	Suren Sharma	6	55	2	
VDC: Sahebganj									
1	Sahebganj	11/30	S-7	STW	Bhumi Mandal	4	45	4	
8	Sahebganj	11/30	S-8	STW	Srinaksadi yadav	5	35	2	
7	Sahebganj	11/30	S-9	STW	Sribidyananda Yadav	10	30	1	
8	Yadav Tole	11/30	S-10	STW	Manchand Yadav	11	70	5	
2	Sahebganj	11/30	S-11	STW	Badri Mehta	2	25	5	
9	Sahebganj	11/30	S-12	STW	Ganesh Dhanu	10	25	4	
VDC: Kaptanganj									
1	Sankarpur	11/30	S-13	STW	Vikram Sharma	10	30	1	
2	Sankarpur	11/30	S-14	STW	Jagdish Singh	1	30	2	
2	Sankarpur	11/30	S-15	STW	Ram Pd. Mehta	7	30	2	
2	Sankarpur	11/30	S-16	Dug Well	Tofi Miya	10	60	10	
4	B. P. Chowk	11/30	S-17	STW	Lalit Mehta	2	35	5	
4	Sankarpur	11/30	S-18	STW	Karanlal Guraun	1	25	2	
VDC: Bhutaha									
1	Nathuni Tola	12/1	S-19	STW	Oli Mahammad	3	70	5	
6	Gupta Tole	12/1	S-20	STW	Umesh Pd. Gupta	10	35	1	
5	Bhutaha	12/1	S-21	STW	Hanif Ansari	8	70	10	
5	Bhutaha	12/1	S-22	STW	Mohammad Idris	10	17	4	
4	Bhutaha	12/1	S-23	STW	Latif	5	25	5	
4	Bhutaha	12/1	S-24	STW	Idris Siddiki	3	80	7	

Inventory of Wells for Arsenic Sample-Testing, contd.

District: Sunsari

Ward No.	Location	Date	Sample No.	Well Type	Owner / Household Head Nearby	Age of Well, yrs.	Approx. Depth, ft.	HH served	Health Effects, if any observed at field level
VDC: Basantpur									
9	Suksana	12/1	S-25	STW	Santosi Mandal	1	40	4	
9	Basantpur	12/1	S-26	STW	Bharat Mandal	5	45	4	
6	Basantpur	12/1	S-27	STW	Sir Narayan Mandal	11	45	6	
5	Suksana	12/1	S-28	STW	Ram Narayan Mehta	11	25	1	
4	Suksana	12/1	S-29	STW	Bachan Lal Mehta	3	25	1	
3	Suksana	12/1	S-30	STW	Manilal Urau	1	20	3	
VDC: Ghuski									
1	Ghuski	12/1	S-31	STW	Malin Ansari	5	60	4	
8	Ghuski	12/1	S-32	STW	Ravi Mandal	3	20	1	
9	Arnama	12/1	S-33	STW	Tahir Ansari	5	60	7	
3	Arnama	12/1	S-34	STW	Rahudi Ansari	4	40	6	
7	Vikrampur	12/1	S-35	STW	Jamil Ansari	3	32	3	
6	Vikrampur	12/1	S-36	STW	Mohammad Ansari	5	60	5	
VDC: Narsingh									
1	Jantachowk S.	12/2	S-37	STW	Abdul Akim	50	17	1	
3	VDC area	12/2	S-38	STW	Jagruk Mandal	9	45	9	
2	VDC South	12/2	S-39	STW	Arjun Pd. Sah	9	40	10	
3	Narsingh	12/2	S-40	STW	Danai Mandal	4	40	6	
5	Tappu	12/2	S-41	STW	Chanchal Yadav	8	60	5	
6	Jadav Tola	12/2	S-42	STW	Rameswar yadav	5	50	7	
VDC: Lauki									
2	Bhansar West	12/2	S-43	STW	Ram Pd. Yadav	4	32	6	
1	Lauki	12/2	S-44	STW	Lachhan Yadav	10	16	1	
6	Lauki	12/2	S-45	STW	Mohan Mandal	1	16	1	
5	HighwayNorth	12/2	S-46	STW	Gopi Pd. Sah	25	16	1	
8	HighwayNorth	12/2	S-47	STW	Baijanath Mandal	10	20	3	
7	HighwayNorth	12/2	S-48	STW	Khadga N. Poddar	9	20	4	

Inventory of Wells for Arsenic Sample-Testing, contd.

District: Sunsari

Ward No.	Location	Date	Sample No.	Well Type	Owner / Household Head Nearby	Age of Well, yrs.	Approx. Depth, ft.	HH served	Health Effects, if any observed at field level
VDC: Sripurjabdi									
7	Kumiyali	12/2	S-49	Dug Well	Sukdev Yadav	10	40	5	
6	Sripur	12/2	S-50	STW	Gopal Sah	3	16	3	
4	Sripur	12/2	S-51	STW	Rani Ma. Vi.	10	25	Public	
3	Sripur	12/2	S-52	STW	Rati Marik	20	15	3	
2	Sripur	12/2	S-53	STW	Ram Lakhan	10	16	2	
1	Sripur	12/2	S-54	STW	Suryalal Sah	10	20	4	
VDC: Haripur									
4	Yadav Tole	12/2	S-55	STW	Srimajelal Bhinduwar	5	45	5	
2	Haripur	12/2	S-56	STW	Mahendra Lal Mandal	5	20	3	
1	Haripur	12/2	S-57	STW	Parvati Sah	10	16	1	
8	Bhantabari	12/2	S-58	STW	Kasim Miya	5	30	1	
8	Bhantabari	12/2	S-59	STW	Podar Yadav	3	40	10	
6	Sadepa	12/2	S-60	STW	Mahanthi yadav	8	40	10	
Flooded Zone / Submerged Area									
	Bhantabari	12/3	S-61	STW	Raghunath Sivpuria	10	36	1	
	Bhantabari, Driver Tole	12/3	S-62	STW	Mukhiya Magar	1	15	1	
	Bhantabari, Southwest	12/3	S-63	STW	Malachhan Sahni	3	20	1	
	Haripur-1, Railway Stn.	12/3	S-64	STW	Kamal Mukhiya	12	18	1	
	Sripur-8, Juddhaganj	12/3	S-65	STW	Idris	18	16	1	
Along Foothill / East-West Highway Area									
VDC: Kusaha									
9	Jamuwa Nahar	12/3	S-66	STW	Jamruddin	1	20	Public	
5	Jamuwa	12/3	S-67	STW	Samid Miya	NA	15	1	
VDC: Lauki									
6	Chowk North	12/3	S-68	STW	Viseswar Mandal	15	25	1	
8	Chowk North	12/3	S-69	STW	Mohan Mandal	10	16	Public	
VDC: Bakraha									
9	Chirauli	12/3	S-70	STW	Hafiz Master	5	70	Public	
9	Chirauli North	12/3	S-71	STW	Islam Ansari	5	25	Public	

Inventory of Wells for Arsenic Sample-Testing, contd.

District: **Sunsari**

Ward No.	Location	Date	Sample No.	Well Type	Owner / Household Head Nearby	Age of Well, yrs.	Approx. Depth, ft.	HH served	Health Effects, if any observed at field level
Inerwa Municipality Northward									
6	Inerwa Chowk	12/3	S-72	STW	Hari Krisna Mehta	4	36	1	
5	Chowk North	12/3	S-73	STW	Dhanilal sadu	15	30	Public	
VDC: Madhesa									
4	Ward-4	12/3	S-74	STW	Sanjiv Shrestha	3	56	Public	
4	Ghopali Tole	12/3	S-75	STW	Sanka N. Shrestha	9	38	1	
VDC: Jhhumka									
5	Dhamrichowk	12/3	S-76	STW	Khodal baba	3	NA	Public	
5	Sisughari	12/3	S-77	STW	Kumar Shrestha	1	45	1	
VDC: Pakali									
3	Kanchi Chowk	12/3	S-78	STW	Jivan Guinde	1	120	1	
3	Mahvir Chowk	12/3	S-79	STW	Sarilal Chaudhry	3	146	1	
Itahari Municipality									
5	Halgada	12/3	S-80	STW	Suman Chaudhri	16	35	1	
2	Sundarpurline	12/3	S-82	STW	Surya Bdr. Bhujel	14	36	1	
VDC: Hansposa									
1	Tarara	12/3	S-81	STW	Bhakta Bdr. Bist	15	32	1	
2	Tarara	12/3	S-83	STW	Dev Kumar Shrestha	1	36	1	
Deep Tube Wells									
DTW Inerwa		12/4	S-84	DTW	DWSO-Sunsari				
DTW Itahari		12/4	S-85	DTW	UC				
DTW Duhabi		12/4	S-86	DTW	UC				

Appendix- 8

This format was used to monitor health effect related possibly with arsenic contamination of groundwater:

Health Effects found Effects	District	VDC, Ward, Place	No. of affected people	Information obtained from
INITIAL STAGE				
Dermatitis				
Keratitis				
Conjunctivitis				
Bronchitis				
Gastroenteritis				
Skin Pigmentation in chest				
SECOND STAGE				
Peripheral Neuropathies				
Hepatopathy				
Melanosis				
Depigmentation				
Hyperkeratosis				
Aldrich-Mees lines (•)				
LATE STAGE				
Gangrene in the limbs				
Malignant neoplasm				
OTHERS				

• *Transverse white striae of finger nails*

Appendix- 9

Based on information collected using format shown in Appendix- 8, a list of places with persons probably affected with arsenic contamination of groundwater is shown here. However, these cases need further clinical analysis for confirmation.

Jhhapa District

Kechana VDC, Ward No. 9, Chalise Tole; 2 persons
Pathamari VDC, Ward No. 4, Kamadbasti; 2 persons
Prithvinagar VDC, Ward No. 5, Prithvinagar; 1 person

Morang District

Mahadeva VDC, Ward No. 3, Hatkhola; 1 person
Mahadeva VDC, Ward No. 2, Chaukihaat; 1 person
Dainiya VDC, Ward No. 8, Nayatola; 1 person
Rangeli VDC, Ward No. 2, Rangeli; 2 persons
Sorabhag VDC, Ward No. 4, Simraha; 1 person
Amahibariyati VDC, Ward No. 2, Bariyati West; 1 person
Amahibariyati VDC, Ward No. 2, Bariyati Southeast; 1 person
Bhaatigachh VDC, Ward No. 7, Hatibandh; 1 person

Sunsari District

Ineruwa VDC, Ward No. 5, Chowk North; 2 persons
Madhesa VDC, Ward No. 4, Ghopali Tole; 1 person

NESS

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Nepal Environmental & Scientific Services Pvt. Ltd. 1992 Kathmandu

Nepal Laboratory Accreditation Scheme
Accredited Laboratory
Accreditation No. Pra. 01/053-54

TEST CERTIFICATE

NS ACCREDITATION NO. PRA. 001/053-054

Entry No. : NCL-187 (W)(92)-10-'99
Sample : Water
Client : Ram Mani Sharma

Date Received : 06.10.1999
Date Completed : 13.10.1999
Sampled By : Client

Arsenic (mg/l)					
Sample	Observed Values	Sample	Observed Values	Sample	Observed Values
J - 1	ND (<0.005)	J - 32	ND (<0.005)	J - 63	ND (<0.005)
J - 2	ND (<0.005)	J - 33	ND (<0.005)	J - 64	0.027
J - 3	0.012	J - 34	ND (<0.005)	J - 65	0.011
J - 4	ND (<0.005)	J - 35	ND (<0.005)	J - 66	ND (<0.005)
J - 5	ND (<0.005)	J - 36	ND (<0.005)	J - 67	0.01
J - 6	ND (<0.005)	J - 37	ND (<0.005)	J - 68	ND (<0.005)
J - 7	ND (<0.005)	J - 38	ND (<0.005)	J - 69	ND (<0.005)
J - 8	ND (<0.005)	J - 39	ND (<0.005)	J - 70	ND (<0.005)
J - 9	0.009	J - 40	ND (<0.005)	J - 71	ND (<0.005)
J - 10	ND (<0.005)	J - 41	ND (<0.005)	J - 72	ND (<0.005)
J - 11	ND (<0.005)	J - 42	ND (<0.005)	J - 73	ND (<0.005)
J - 12	ND (<0.005)	J- 43	ND (<0.005)	J - 74	ND (<0.005)
J - 13	ND (<0.005)	J - 44	ND (<0.005)	J - 75	ND (<0.005)
J - 14	ND (<0.005)	J - 45	ND (<0.005)	J - 76	ND (<0.005)
J - 15	ND (<0.005)	J - 46	ND (<0.005)	J - 77	ND (<0.005)
J - 16	ND (<0.005)	J - 47	ND (<0.005)	J - 78	ND (<0.005)
J - 17	ND (<0.005)	J - 48	ND (<0.005)	J - 79	ND (<0.005)
J - 18	ND (<0.005)	J - 49	ND (<0.005)	J - 80	ND (<0.005)
J - 19	ND (<0.005)	J- 50	ND (<0.005)	J - 81	ND (<0.005)
J - 20	ND (<0.005)	J - 51	ND (<0.005)	J - 82	ND (<0.005)
J - 21	ND (<0.005)	J - 52	ND (<0.005)	J - 83	ND (<0.005)
J - 22	ND (<0.005)	J - 53	ND (<0.005)	J - 84	ND (<0.005)
J - 23	ND (<0.005)	J - 54	ND (<0.005)	J - 85	ND (<0.005)
J - 24	ND (<0.005)	J - 55	ND (<0.005)	J - 86	ND (<0.005)
J - 25	ND (<0.005)	J - 56	ND (<0.005)	J - 87	0.007
J - 26	ND (<0.005)	J - 57	ND (<0.005)	J - 88	ND (<0.005)
J - 27	ND (<0.005)	J - 58	ND (<0.005)	J - 89	ND (<0.005)
J - 28	ND (<0.005)	J - 59	ND (<0.005)	J - 90	ND (<0.005)
J - 29	ND (<0.005)	J - 60	ND (<0.005)	J - 91	ND (<0.005)
J - 30	ND (<0.005)	J - 61	ND (<0.005)	J - 92	ND (<0.005)
J - 31	ND (<0.005)	J - 62	ND (<0.005)		

Method of analysis: Silverdiethyl dithiocarbamate absorptiometric method

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NOTE:
1. The result listed refer only to the tested samples and applicable parameters. Endorsement of products is neither inferred nor implied.
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Tel. No: 977-1-215875, 244989, Fax No. 977-1-226028, E-mail: ness@mos.com.np

TEST CERTIFICATE

NS ACCREDITATION NO. PRA. 001/053-054

Entry No.	: NCL-208 (W)(72)-11-'99	Date Received	: 25.11.1999
Sample	: Water	Date Completed	: 30.11.1999
Client	: Ram Mani Sharma	Sampled By	: Client
Parameter	: Arsenic (As)	Location	: Morang

Arsenic (mg/l)					
Sample	Observed Values	Sample	Observed Values	Sample	Observed Values
M - 1	ND (<0.005)	M - 31	ND (<0.005)	M - 61	ND (<0.005)
M - 2	ND (<0.005)	M - 32	0.02	M - 62	ND (<0.005)
M - 3	ND (<0.005)	M - 33	ND (<0.005)	M - 63	ND (<0.005)
M - 4	ND (<0.005)	M - 34	0.05	M - 64	ND (<0.005)
M - 5	ND (<0.005)	M - 35	ND (<0.005)	M - 65	ND (<0.005)
M - 6	ND (<0.005)	M - 36	0.005	M - 66	ND (<0.005)
M - 7	ND (<0.005)	M - 37	ND (<0.005)	M - 67	ND (<0.005)
M - 8	ND (<0.005)	M - 38	ND (<0.005)	M - 68	ND (<0.005)
M - 9	ND (<0.005)	M - 39	ND (<0.005)	M - 69	ND (<0.005)
M-10	ND (<0.005)	M - 40	ND (<0.005)	M - 70	ND (<0.005)
M - 11	ND (<0.005)	M - 41	ND (<0.005)	M - 71	ND (<0.005)
M - 12	ND (<0.005)	M - 42	0.022	M - 72	ND (<0.005)
M - 13	ND (<0.005)	M - 43	ND (<0.005)	M - 73	ND (<0.005)
M - 14	0.011	M - 44	ND (<0.005)	M - 74	ND (<0.005)
M - 15	ND (<0.005)	M - 45	0.021	M - 75	ND (<0.005)
M - 16	ND (<0.005)	M - 46	ND (<0.005)	M - 76	ND (<0.005)
M - 17	ND (<0.005)	M - 47	ND (<0.005)	M - 77	ND (<0.005)
M - 18	ND (<0.005)	M - 48	ND (<0.005)	M - 78	0.0077
M - 19	ND (<0.005)	M - 49	ND (<0.005)	M - 79	ND (<0.005)
M - 20	ND (<0.005)	M - 50	0.022	M - 80	ND (<0.005)
M - 21	0.017	M - 51	ND (<0.005)	M - 81	ND (<0.005)
M - 22	ND (<0.005)	M - 52	ND (<0.005)	M - 82	ND (<0.005)
M - 23	ND (<0.005)	M - 53	ND (<0.005)	M - 83	ND (<0.005)
M - 24	ND (<0.005)	M - 54	ND (<0.005)	M - 84	ND (<0.005)
M - 25	ND (<0.005)	M - 55	ND (<0.005)	M - 85	ND (<0.005)
M - 26	ND (<0.005)	M - 56	ND (<0.005)	M - 86	ND (<0.005)
M - 27	ND (<0.005)	M - 57	ND (<0.005)	M - 87	ND (<0.005)
M - 28	0.042	M - 58	0.019	M - 88	ND (<0.005)
M - 29	ND (<0.005)	M - 59	ND (<0.005)	M - 89	ND (<0.005)
M - 30	ND (<0.005)	M - 60	ND (<0.005)	M - 90	ND (<0.005)

Method of analysis: Silverdiethyl dithiocarbamate absorptomeric method

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Accredited Laboratory
Accreditation No. Pra. 01/053-54

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NOTE:
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TEST CERTIFICATE

NS ACCREDITATION NO. RA. 001/053-054

Entry No.	: NCL-214 (W)(104)-11-'99		Date Received	: 06.12.1999
Sample	: Water		Date Completed	: 13.12.1999
Client	: Ram Mani Sharma		Sampled By	: Client
Parameter	: Arsenic (As)			

		Arsenic (mg/l)			
Sample	Observed Values	Sample	Observed Values	Sample	Observed Values
S - 1	ND (<0.005)	S - 30	ND (<0.005)	S- 59	0.053
S - 2	ND (<0.005)	S - 31	ND (<0.005)	S- 60	0.017
S - 3	ND (<0.005)	S - 32	ND (<0.005)	S- 61	0.005
S - 4	ND (<0.005)	S - 33	ND (<0.005)	S- 62	0.0057
S - 5	ND (<0.005)	S - 34	ND (<0.005)	S- 63	0.026
S - 6	ND (<0.005)	S - 35	ND (<0.005)	S- 64	ND (<0.005)
S - 7	ND (<0.005)	S - 36	ND (<0.005)	S- 65	0.0063
S - 8	ND (<0.005)	S - 37	ND (<0.005)	S - 66	0.012
S - 9	ND (<0.005)	S - 38	ND (<0.005)	S - 67	ND (<0.005)
S - 10	ND (<0.005)	S - 39	ND (<0.005)	S - 68	ND (<0.005)
S- 11	ND (<0.005)	S - 40	0.015	S - 69	ND (<0.005)
S - 12	ND (<0.005)	S - 41	ND (<0.005)	S - 70	ND (<0.005)
S - 13	ND (<0.005)	S- 42	ND (<0.005)	S - 71	0.014
S - 14	ND (<0.005)	S- 43	ND (<0.005)	S - 72	ND (<0.005)
S - 15	ND (<0.005)	S- 44	ND (<0.005)	S- 73	ND (<0.005)
S - 16	ND (<0.005)	S - 45	ND (<0.005)	S- 74	ND (<0.005)
S - 17	ND (<0.005)	S- 46	ND (<0.005)	S- 75	ND (<0.005)
S - 18	ND (<0.005)	S- 47	ND (<0.005)	S- 76	ND (<0.005)
S - 19	ND (<0.005)	S- 48	ND (<0.005)	S- 77	ND (<0.005)
S - 20	ND (<0.005)	S- 49	ND (<0.005)	S- 78	ND (<0.005)
S - 21	ND (<0.005)	S- 50	ND (<0.005)	S- 79	ND (<0.005)
S - 22	ND (<0.005)	S- 51	0.075	S - 80	ND (<0.005)
S - 23	ND (<0.005)	S- 52	ND (<0.005)	S - 81	ND (<0.005)
S - 24	ND (<0.005)	S- 53	0.0063	S - 82	0.023
S - 25	ND (<0.005)	S- 54	ND (<0.005)	S - 83	ND (<0.005)
S - 26	ND (<0.005)	S- 55	0.027	S - 84	ND (<0.005)
S - 27	ND (<0.005)	S- 56	0.019	S - 85	ND (<0.005)
S - 28	ND (<0.005)	S- 57	0.011	S - 86	ND (<0.005)
S - 29	ND (<0.005)	S- 58	0.012		

As determination in water sample has been performed by Silverdiethyl dithiocarbamate absorptomeric method. In this method, As is converted in to Arsenic Hydride by chemical treatment and the evolved Arsenic Hydride is absorbed in chloroform solution of silver Diethyl di-thiocarbonate. The intensity of developed purple color is measured at 510nm. As in sample is determined by comparing its absorbance by using standard curve.

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NOTE:

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TEST CERTIFICATE

NS ACCREDITATION NO. PRA. 001/053-054

Entry No : NCL-214 (W)(104)-12-'99
Sample : Water
Client : Ram Mani Sharma
Parameter : Arsenic (As)

Date Received : 06.12.1999
Date Completed : 19.12.1999
Sampled By : Client

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S. N.	Arsenic (mg/l) Sample	Observed Values
1.	M - 78	ND (<0.003)
2.	S - 53	0.003
3.	S - 54	ND (<0.003)
4.	S - 55	0.026
5.	S - 56	0.028
6.	S - 57	0.008
7.	S - 58	0.011
8.	S - 59	0.044
9.	S - 60	0.018
10.	S - 61	0.007
11.	S- 62	0.006
12.	S - 63	0.012
13.	S - 64	0.004
14.	S - 65	0.005
15.	S - 66	0.012
16.	S - 40	0.009
17.	S - 71	ND (<0.003)
18.	S - 82	0.019

Remarks: Determination of Arsenic in water samples was performed by Hydride generation Technique.

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