CONTAMINATION OF AGRICULTURAL LAND BY ARSENIC FROM IRRIGATED WATER

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A thesis Submitted
by

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CERTIFICATE OF APPROVAL

The thesis titled "**CONTAMINATION OF AGRICULTURAL LAND BY ARSENIC FROM IRRIGATED WATER**" submitted by **Musammat Shahinara Begum**, Student Number: 040504504(F), Session: April, 2005, has been accepted as satisfactory in fulfillment of the requirement for the degree of Master of Engineering in Environmental on 27th January, 2009.

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January, 2009

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Signature of the student

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ABSTRACT

Ensuring safe drinking water is one of the prime objectives of the Government and the others those are working in the water supply sector in Bangladesh. Arsenic is not only present in water but also in soil which are the main media of food production. The present study has been conducted to observe the contamination of agricultural land by arsenic from irrigated water. The study was conducted to find out a correlation between arsenic concentration in irrigation water and soil nutrient of different locations of Sadar upazila, Keshabpur upazila and Jhikargacha upazila of Jessore district.

From this study it has been found that water of a significant number of irrigation wells in Jessore district (Sadar upazila, Jhikorgacha upazila and Keshabpur upazila) are contaminated by arsenic. There is no significant correlation between arsenic in ground water and other important parameters of ground water.

In Keshabpur upazila, irrigated soil was collected from six locations and corresponding irrigation water also collected and tested. However, it is found that relation between arsenic concentration of irrigation water and arsenic concentration in irrigated land is insignificant.

The food chain issue is becoming more and more important as there is increased evidence of arsenic buildup in crops and different types of vegetation. In Samta village of Jessore district, rice and wheat are irrigated with arsenic affected water and it has been found that irrigated lands are also affected by arsenic. Average arsenic concentrations in rice grain are higher than wheat. However, the concentration of arsenic in rice and in wheat grain is insignificant.

Arsenic concentration in root, grain and straw of rice is higher than wheat. The values obtained with grain, straw and root agreed well with the general trend of variation, i.e., grain<straw<root.

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CHAPTER 1
INTRODUCTION

1.1 Background of the Study

Bangladesh is the largest delta in the world. It has fertile agricultural land and abundant water for crop production. The widespread presence of arsenic in groundwater at levels above the drinking water standard is a major concern in Bangladesh (BGS/ DPHE, 2001). In the 1980's and 1990's, Bangladesh made enormous strides in supplying its population with safe drinking water through the provision of shallow tubewells. Agricultural productivity holds the key to the country's overall economic growth and welfare of its people. In recent years, agricultural production in Bangladesh has increased significantly. Thus, the country's food production is heavily dependent on irrigation. There are two major sources of irrigation water in Bangladesh - surface water and groundwater.

Bangladesh Agricultural Development Corporation (BADC) introduced shallow tubewells (STW) as irrigation equipment for the first time in 1968. Later in 1973 deep tubewell (DTW) irrigation started. In Bangladesh, the pumps used in irrigation are classified as shallow tubewell (STW), deep-set shallow tubewell (DSTW), very deep set shallow tubewell (VDSTW), and deep tubewell (DTW). The STW, DSTW and VDSTW are scientifically termed as suction mode pumps and DTW as force mode pump.

Water is a basic need of man along with food and air. At present arsenic pollution in groundwater is particularly challenging in Bangladesh. Now Arsenic is not only present in water but also in soil which may enter into food chain. British Geological Survey showed in 1990s that 27% of shallow tubewells had Arsenic contamination above the Bangladesh standard of 0.05 mg/l (Ferdausy, S.M. 2005). The Survey also Identified that 269 Upazilas as hot spots where large numbers of shallow tube wells were contaminated by arsenic. In 1997, a program was initiated by United States Agency for International Development (USAID) to prepare a map of arsenic concentration in tubewells water of Bangladesh. The study showed that 45% ground water of Bangladesh is contaminated by arsenic. (i.e. arsenic concentration greater than the 0.05 mg/L). The Survey and Monitoring Project of Bangladesh Agricultural Development Corporation tested irrigation water quality of STWs, DTWs and surface water about 1926 samples. Out of 1926 samples 172 are unsuitable for drinking and 33 samples are unsuitable for irrigation. These are found in 49 Upazila and 17 districts (BADC, 2007). Arsenic also found in Soil which is the main media of food chain. Therefore, there is a possibility of the presence of arsenic in the agricultural land. Arsenic concentration in agricultural soil is very dynamic which varies with time and also varies significantly with depth (Saha, 2006).

Boro cultivation and irrigation increased together since 1970 and from 1980 up to present time, the area under ground water irrigation increased by almost an order of magnitude (Harvey et al., 2005). The increased concentration of arsenic in irrigation water is likely to result in increased concentration in plant and food grains. In a study (Abedin et al., 2002) where a Bangladesh paddy variety was irrigated with water containing up to 0.8 mg/l of arsenate, the arsenic concentration in root, straw and paddy husk also increased significantly. Masud (2003) and Ali et al., (2003) also reported higher accumulation of arsenic in root of paddy plant samples irrigated with arsenic bearing water in Munshigonj and Sonargaon. Shaha,G.C (2006) summarized that close to 1000 metric tons of arsenic cycled each year through irrigation water. The estimates are high for south-western and south-central regions of Bangladesh, where both irrigation intensity and arsenic concentration in shallow tubewells are very high. Accumulation of arsenic in irrigated surface soils is expected and number of studies have reported relatively higher levels of arsenic in paddy field soil irrigated with arsenic bearing ground water (e.g., Ullah, 1998; Jaahiruddin et al., 2000; Meharg and Rahman, 2003; Huq et al., 2003; Ali et al., 2003b; Farid et al., 2005; Jahiruddin et al., 2005; Islam et al., 2005). However there is no data/ reports in Jessore district such Keshabpur, Jhikorgacha, Sharsha and Jessore Sadar Upazila to find relation of arsenic concentration in irrigation water and soil nutrient.

Available data suggested that vegetables are strongly correlated with arsenic content in irrigation water and arsenic content in root-soil. Shaha (2006) showed that higher levels of arsenic (exceeding 1 mg/kg, Australian food standard) were found in edible parts of potato, tomato, data shak and lal shak. Soil has a central position in the environmental cycle of arsenic. From soil, arsenic may enter into plant and soil particles absorb arsenic by water. Thus there is a possible co-relation between arsenic and others parameter of ground water and soil. On the other hand there are no reports on compare of arsenic concentration between Wheat and Paddy including different varieties. Therefore it is very important to find the co-relation between arsenic and other parameters of ground water (like Iron, Sulphate and Phosphate) and co-relation between arsenic concentration of ground water and arsenic concentration of soil.

1.2 Objectives with Specific Aims and Possible Outcome

Though the country's food production is heavily dependent on irrigation and Soil, fertilizer, seed and water are dependent with one another. Thus Among these, if one has poor quality are affected by economy of the country even human being. Therefore food security and safe food production is very important for any country. However the overall objectives of the study are:

- To assess possible correlation between Arsenic concentration in irrigation water and soil nutrient in Keshabpur, Jhikorgacha and Sadar Upazilas of Jessore district.
- To assess the effect of arsenic in ground water or arsenic in soil and in rice, wheat plants in Sharsha upazila.
- To prepare GIS based maps of irrigation water quality and soil nutrient for selected areas.

1.3 Outline of the Methodology

In order to assess the contamination of agricultural land by arsenic and concentration of arsenic in soil and in water of STW, DTW, data were collected from the study areas. Water quality parameters of each sample were measured using field kit (LAMOTTE, HACH) in the laboratory of BADC at Dhaka.
Soil and water sample were collected from Keshabpur, Jhikorgacha and Sadar Upazilas. Arsenic and iron concentration was tested at BUET lab of seven soil samples. In this study Sharsha upazila was selected for analysis the effect of arsenic in the wheat and paddy plants. Nutrient concentration of wheat and paddy plant samples was tested in the laboratory of BADC at Dhaka. Data were analyzed with the help of statistical software like SPSS, MS Excel etc. For creating geographic map, the Arc View 3.3 software was used. Arsenic, Iron, Sulphate and phosphate concentration of water samples and arsenic, iron concentration of soil samples were shown in the GIS based map. Detailed methodologies for each item of works have been described in the respective Chapters of the thesis, and hence are not elaborated here.

1.4 Organization of the Thesis

This thesis consists of five chapters. The first chapter describes the background of the study and sets out its major objectives. Chapter two (Literature Review) briefly describes the overview of arsenic concentration in ground water and importance of ground water in the agriculture of Bangladesh. This chapter also presents the aquifer system of the entire country and provides an overview of the status of ground water irrigation in the country. The literature review provided in this chapter identifies the information gaps and highlights the importance of this research work. Chapter three provides necessary methodology to achieve the target of the study. Chapter four presents the output of this research work, which include correlation between arsenic and other parameters of ground water, correlation between arsenic concentration of soil and arsenic concentration of ground water in Keshabpur upazila and GIS based maps of arsenic, iron, sulphate and phosphate concentration of Keshabpur, Jhikorgacha and Sadar upazila of Jessore. This chapter also assesses the effect of arsenic in irrigation water in rice and wheat at Sharsha upazila. Chapter five presents the major conclusions of the study and also provides recommendations for future study.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Irrigation is the artificial application of water to soil for the purpose of crop production. Irrigation water is supplied to supplement the water available from rainfall and the contribution to soil moisture from ground water. In many areas of the world the amount and timing of rainfall are not adequate to meet the moisture requirement of crops and irrigation is essential to raise crops necessary to meet the needs of food and fiber. Irrigation is an age-old art, as old as civilization. The increasing need for crop production for the growing population is causing the rapid expansion of irrigation throughout the world. In the comprehensive strategy needed for the conservation and development of our water recourses, several factors are too kept in view. These include the availability of water, its quality, location, distribution and variation in its occurrence, climate conditions, nature of the soil, nutrient present in soil and socio-economic conditions. In dealing with each of these, every effort must be made to make the best use of water, so as to make possible a high level of continuous production.

In Bangladesh, ground water is the major source of water for irrigation of crops in the dry season. Over the last few decades, the irrigation scenario in Bangladesh has been changing with more and more use of ground water from the shallow aquifer in irrigation. Shallow tubewell is low-cost irrigation equipment and its technology is comparatively simple. That is why the number of shallow tubewell has been increasing tremendously in last thirteen years without proper consideration of its impact. As a result more and more shallow tubewells are being inoperative due to lowering of ground water level beyond their suction limit during the later part of the irrigation season. A good understanding of the irrigation water sources and irrigation equipment used in Bangladesh are needed in order to assess the effect of lowering of ground water level on shallow tubewell irrigation.

Bangladesh, as a developing country, agriculture plays a key role in the overall economic performance of the country, not only in terms of its contribution to gross domestic product (GDP), but also as a major source of foreign exchange earnings, and in providing employment to a large segment of the population, particularly the poor. All of these can not possible without proper irrigation. Scientific management of irrigation water provides the best insurance against weather-induced fluctuation in total food production. This is only way in which can make the agriculture competitive and profitable. Ground water is the major source of water in Bangladesh for irrigation. Ground water is extensively used in Bangladesh for drinking and irrigation purposes. About 97% of the Population in this country uses ground water for drinking and domestic purposes and 72% of current irrigation demand is met by groundwater sources. Arsenic contaminated ground water has become as one of the largest natural calamities of Bangladesh. The arsenic extracted from ground water for irrigation accumulated at the top soil which is the central position in the environmental cycle of arsenic. From the soil, arsenic may enter in the food chain by plant uptake and animal ingestion of soil particles. This chapter provides an overview of water quality parameters and soil nutrients and presence of arsenic in water and soil.

Irrigation and hence food production is becoming more and more dependent on ground water resources. Ground water in Bangladesh is contaminated with arsenic which may cause accumulation of arsenic in rice plant. On the other hand this irrigation water continuously added arsenic to the soil during irrigation season many researches reported about reduction of growth in rice grown in arsenic contaminated soil or water so ground water exploitation and utilization has become a very important issue throughout the country. For a particular area and aquifer judicious, careful and economic utilization of the ground water depends on reliable data and information on the aquifer. Future national agricultural policy, national water policy and national irrigation policy and strategies for implementation of these policies should be based on the present and past information regarding the concerned ground water basin. As surface water infiltrates and is stored in soil formation through surface percolation and deep percolation, judicious use of ground water needs good understanding of some of the basic information of soils, sub soils and aquifers. This chapter briefly describes the sources of irrigation water, arsenic concentration in ground water and importance of ground water in the development of agriculture of Bangladesh.

2.2 Sources of Irrigation Water in Bangladesh

The main sources of irrigation water are:

- Surface water in ponds, khals, bills, haor, boars, canals, lakes and rivers.
- Ground water in shallow and deep aquifer.
- Rain water

The two major sources of irrigation water in Bangladesh are surface water and ground water. During boro (dry) season due to shortage of surface water ground water is extensively used as a source of irrigation. Figure 2.1, Figure 2.2 and Figure 2.3 shows the increase of ground water irrigation and at the same time decrease of surface water irrigation during 1970-2007 (Source of data: Harvey et al., 2002, and BADC, 2000-2008). Figure 2.2 during 1970 to 1982, the contribution of surface water was more than that of ground water; during 1984-85 the contribution from the two sources was almost similar. During the last two decades, the area irrigated by ground water increased significantly (Figure 2.1). For example, according to MOA (2006), in boro season of 2006, the total irrigated area was 4759717 hectares, of which 3849510 ha or about 80.87% was irrigated by ground water and 910207 ha or about 19.13% was irrigated by surface water. The contribution of ground water to total irrigated area has increased from 41% in 1982-83 to 71% in 1996-97; to about 75% in 2004 and to 80.87% in 2006. The contribution of surface water has declined from 59% to less than 20% during this period.

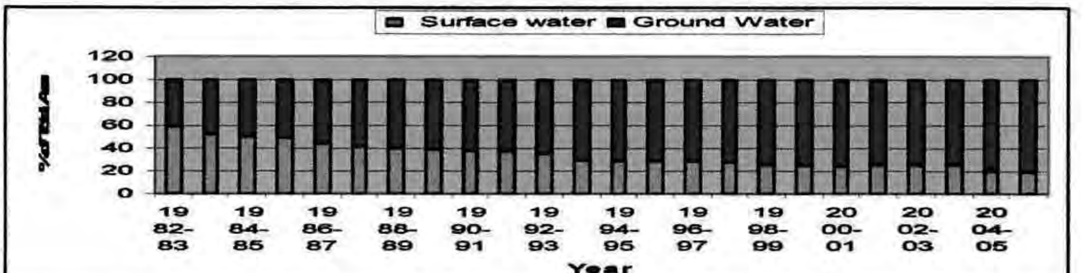


Figure 2.1: Percent of area irrigated by surface and ground water sources.
(Data Source: NMIC, 1999/2000, GoB, 1998, Harvy et al., 2002, and BADC, 2005)

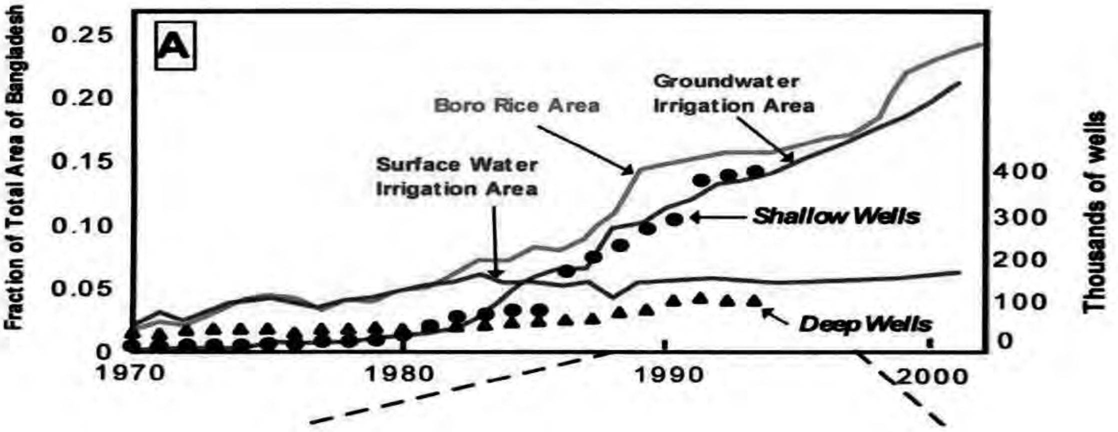


Figure 2.2: Source of water, irrigation equipment and irrigated area in Bangladesh. (Source: Harvey et al., 2002)

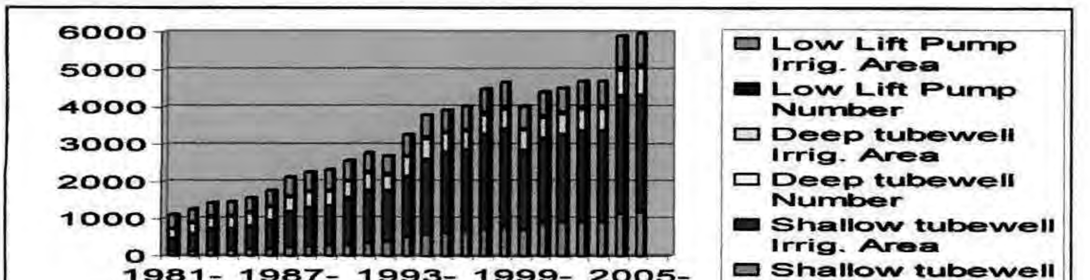


Figure 2.3: Comparison among different types of irrigation equipment and irrigated area in Bangladesh for the year 2006(BADC, 2006).

2.2.1 Irrigation equipment

In Bangladesh irrigation of boro crops is heavily dependent on ground water. This water is mainly abstracted by shallow tubewell (STW), deep set shallow tubewell (DSTW), very deep set shallow tubewell (VDSTW), deep tubewell (DTW), artesian well, dug well, and non-mechanized tubewells. Among them STW with motor pumps are very popular irrigation equipment. Mainly shallow tubewells having a discharge of about 14 l/s capacity are used in irrigation. Special emphasis was given on the use of STW in irrigation in view of the availability of water at shallow depth, comparatively lower unit cost and relatively easy drilling, operation and maintenance technology. All shallow tubewells including deep set shallow tubewell (DSTW) and very deep set shallow tube well (VDSTW) abstract water from shallow aquifer.

Table: 2.1 Irrigation equipment and irrigated area in different years

Season	Equipment/ Area	Type of irrigation			
		DTW	STW	LLP & FP	Other
Year 2000	No. of equipment	23536	707574	58058	135263
	Irrigated area(ha)	529640	2122511	581801	322578.34
	% of area	14.89	59.68	16.35	9.08
Year 2001	No. of equipment	23182	865213	71309	130719
	Irrigated area(ha)	538264	2295067	603787	321090.17
	% of area	14.29	60.94	16.24	8.52
Year 2002	No. of equipment	23001	893359	77007	88242
	Irrigated area(ha)	530291	2355033	628748	335695.37
	% of area	13.77	61.17	16.33	8.73
Year 2003	No. of equipment	23434	924023	79872	72562
	Irrigated area(ha)	587937	2409407	664018	356876.52
	% of area	14.63	59.96	16.53	8.88
Year 2004	No. of equipment	24718	925152	77784	64235
	Irrigated area(ha)	589482	2429127	630668	38912.41
	% of area	14.58	60.07	15.80	9.55
Year 2005	No. of equipment	27117	1128991	99255	-
	Irrigated area(ha)	654189	3159899	838377	134881
	% of area	13.66	66.00	17.51	2.83
Year 2006	No. of equipment	28289	1182525	119135	-
	Irrigated area(ha)	700662	3120607	803170	135278
	% of area	14.72	65.56	16.87	2.85
Year 2007	No. of equipment	29177	1202728	107293	-
	Irrigated area(ha)	1202728	3196127	810027	137064
	% of area	14.85	65.46	16.59	2.81

(Data Source: BADC, 2001; BADC, 2002; BADC, 2003; BADC, 2004 and BADC, 2005, BADC, 2006, 2007)

Figure 2.4 shows irrigated area by different technologies during 1970-2007 (Source of data: Harvey et al., 2002 and BADC, 2000-2007). From this figure it is clear that during 1983-2007 the area under irrigation by surface water has varied from 15% to

22%; while the area under irrigation by deep tubewell varied from 13% to 17% and that of shallow tubewell has increased from 24% to 66%.

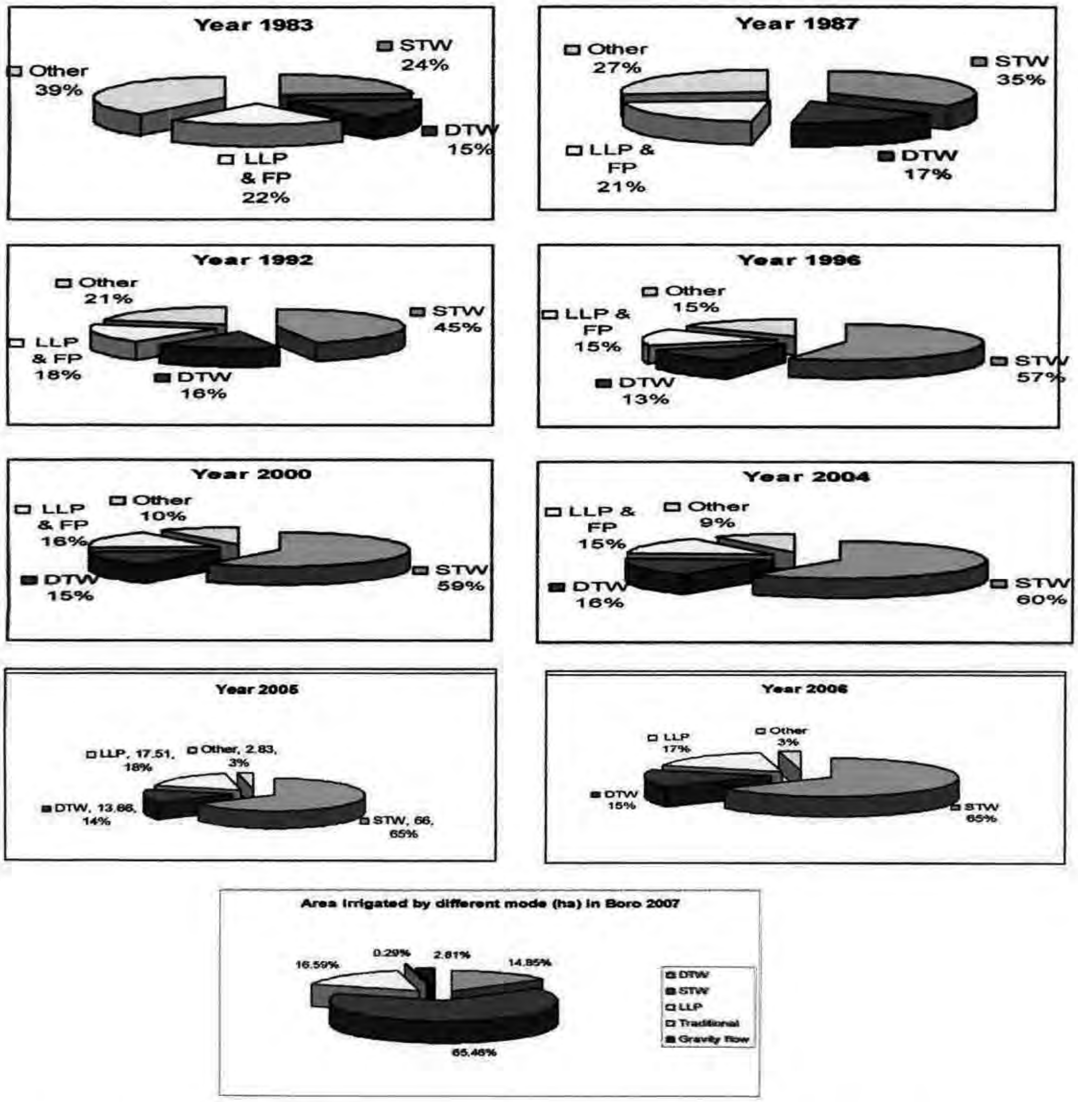


Figure 2.4 Area irrigated in Bangladesh by different technologies during 1983- 2007 (Data Source: BADC, 2005, BADC, 2006, BADC, 2007)

Therefore, ground water is mostly used in Bangladesh during dry season. DTW and STW are normally used in Bangladesh to collect ground water. The trends in the nature of irrigation soon changed to ground water abstraction, initially through deep tube wells (DTWs), followed by introduction of shallow tube wells, driven by surface mounted centrifugal pump.

According to the report of Ministry of Agriculture (MOA, 2007), in boro season of 2007, a total of 1202728 shallow tubewells,29177 deep tubewells, 107293 low lift and floating pumps, and other equipments were used for irrigation all over Bangladesh. Table 2.1 shows that contribution of STW is increasing day by day and the number of STW have increased by 65% during last seven year period. The contribution of surface and ground water sources to total irrigated area has changed considerably over time.

2.2.2 Aquifer

Ground water is water located beneath the ground surface in soil pore spaces and in the fractures of lithologic formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become fully saturated with water is called the water table. Ground water is recharged from and eventually flows to the surface naturally; natural discharge often occurs at springs and seeps, streams and can form oases or wetlands. Ground water is also often withdrawn for agricultural, municipal and industrial use by constructing and operating extraction wells.

Typically ground water is thought of as liquid water flowing through shallow aquifers, but technically it can also include soil moisture, permafrost (frozen soil), immobile water in very low permeability bedrock and deep geothermal or oil formation water. Ground water is hypothesized to provide lubrication which can possibly aid faults to move. Ground water can be a long-term 'reservoir' of the natural water cycle (with residence times from days to millennia) as opposed to short-term water reservoirs like the atmosphere and fresh surface water (which have residence times from minutes to years). The figure shows how deep ground water (which is quite distant from the surface recharge) can take a very long time to complete its natural cycle. Ground water is naturally replenished by surface water from precipitation, streams and rivers when this recharge reaches the water table. It is estimated that the volume of ground water comprises 30.1% of all freshwater resource on earth compared to 0.3% in surface freshwater; the icecaps and glaciers are the only larger sources of fresh water on earth at 68.7%.

Ground water makes up about twenty percent of the world's fresh water supply, which is about 0.61 percent of the entire world's water including oceans and permanent ice. (Environment Canada Website)

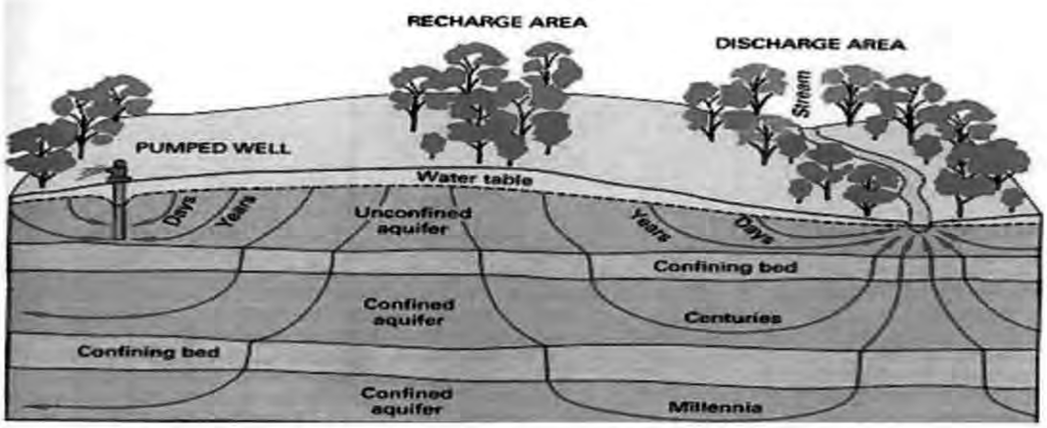


Figure 2.5: Different aquifer of soil formation (Source: Environmental Canada Website, 2008)

The study of water flow in aquifers and the characterization of aquifers is called hydrogeology. Related terms include: an aquitard, which is an impermeable layer along an aquifer and an aquiclude which is a solid, impermeable area beneath an aquifer. Aquifers can occur at various depths.Those closer to the surface are not only more likely to be exploited for water supply and irrigation, but are also more likely to be topped up by the local rainfall. Water bearing strata that is shallow depth (depth is area depended within 100m) below ground surface with an over laying thin layer of clay /silt blanket. Water abstracted by hand tube-well from this aquifer is known as shallow tubewell. Most of the shallow shallow tubewells (STW) in Bangladesh is contaminated by arsenic which excced irrigation limit (0.1ppm).

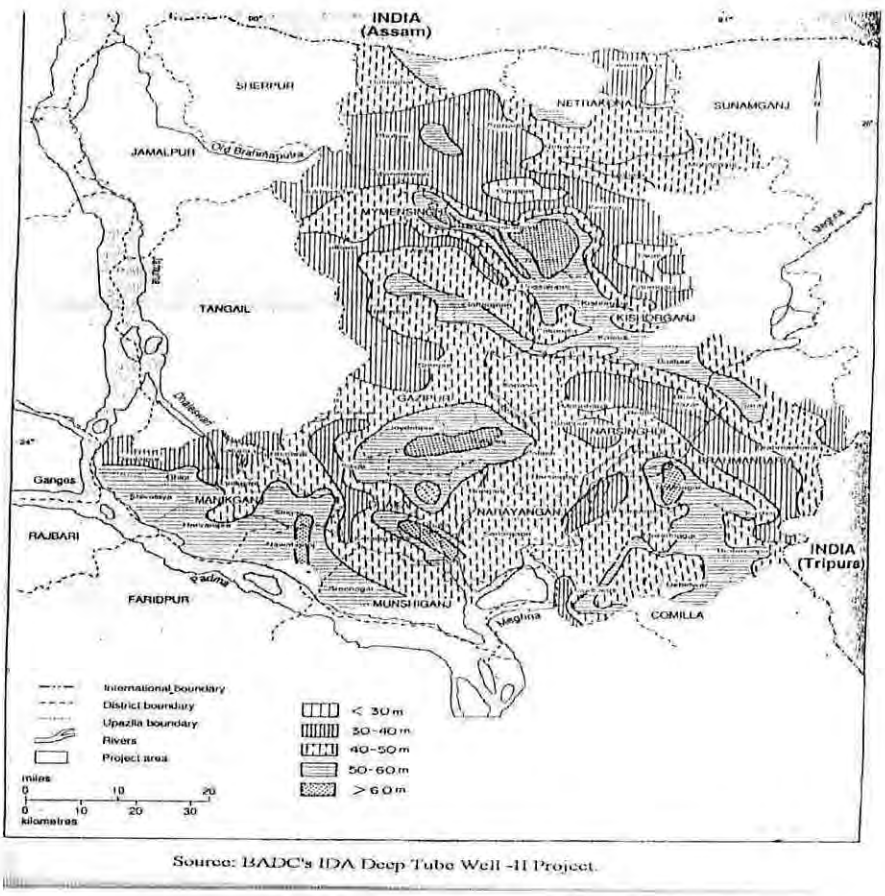
The hydrograph of the ground water level at different areas of Bangladesh indicates that part of the recharge water is being lost through evaporation was well as by the runoff into the streams and rivers before it is used in irrigation season particularly in the month of January. Ground water level is declined during the periods from August to December where it amounts to a few meters. The resultant fluctuation in ground water level is however multiplied by the specific yield value of the soil strata to estimate the available recharge. But it varies from 30 mm to 300 mm per unit area.

Ahmed et al. (1991) made a simple approach to assess ground water recharge in Muktagacha aquifer under Mymensingh district where rainfall was considered as the single source of recharge. An empirical relation known as Shegal's method was used for calculating recharge. In this investigation recharge was physically considered as the result of the annual rainfall. Accordingly an average recharge of 596 mm was estimated from an average annual rainfall of 2654 mm in the study area. It was found that the recharge of the aquifer started in May and continued up to October. Using soil moisture balance method, the potential recharge of 201.07 cm was obtained from the total annual rainfall of 1077.57 cm during the period of January, 1998 to May 1993; which was about 18.66% of the total rainfall (Kabir, 1993). Hasan (1994) reported that the annual recharge rate varied substantially among the different districts such as Kustia, Rajshahi and Jessore have much lower recharge rates than others. These districts can not support full development of agriculture from ground water alone. On the other hand, Sylhet, Mymensingh, Dinajpur and Rangpur districts have comparatively higher recharge rates and agriculture in these districts could be supported significantly by groundwater.

Islam (1997) determined the annual ground water recharge using groundwater level hydrograph analysis method at Dhunat Upazila of Bogra district. The annual recharge to the aquifer was found to be 546 cm which was about 27.7% of the total rainfall of 1982.01 cm during the period of 1986 to 1995. Ahsan (1997) made an assessment in Netrakona sadar upazila and found that the recharge and depletion characteristics were found almost in equilibrium condition. The long term trend of ground water level was found to be in declining trend in the last decade.

Generally the location, depth, size and composition of aquifers are determined by highly sophisticated methods of surveying like seismic survey. But due to non availability of such facilities, BADC prepared aquifer map for a few parts of the country on the basis of lithological data and soil profile collected from International

Development Agency (IDA) deep tubewell project. Depth to the top of main aquifer of the north central and north east hydrological region was prepared on the basis of the data of IDA project that has been shown in Figure 2.1. From this figure it is observed that in Gouripur of Mymensing district and Tarail of Kishoreganj district the top of main aquifer is within 30 m depth and that of old Brahmaputra flood plain and young Jamuna flood plain is within 30 to 40 feet from the surface of the soils. In major parts of Kapasia, Gazipur, Narshingdi, Sonargaon and Narayangonj upazilas are in the areas where aquifers lie below 40-50 m from top of the surface. In major parts of Kishoreganj and Joydevpur main aquifer like at a depth of 50-60 m from the top of soils.



Source: BADC's IDA Deep Tube Well -II Project.

Figure 2.6: Depth to the top of main aquifer (Source: BADC, 1992).

2.3 Ground Water Quality

Quality of irrigation water is mostly dependent on pH, Electrical Conductivity (EC), Total Alkalinity (TA), Chloride (Cl), Phosphate (PO_4), Total Hardness (TH), Total Dissolved Solids (TDS), Calcium (Ca), Magnesium (Mg), Sodium (Na) and Potassium (K) .

Pure Water is not available in nature nor it is desirable for water supply. Impurities present in natural water may be grouped into the following four catagories;

- Impurities in mineral origin
- Impurituues organic origin
- Living impurities
- Radioactive impurities.

These impurities may be present in suspension, solution or psedo-solution. Some of the water quality parameters respond to human senses of sight (turbidity, colour), taste (salty, offensive) and smell but the presence of pathogens and poisons in drinking water can not be identified by humen senses.

In Bangladesh Irrigation depend on mainly ground water. It is affected by the nature of the soils and rocks through which it passes. Ground water quality is affected by pollutants of urban, industrial and agricultura origins. The same problem that affect surface waters also affect ground waters, though they can take many years to become evident and are almost impossible to deal with. From agricultural activities, these include chemical pesticides and herbicidies, nutrient from fertilizer.

Table 2.2 Water Quality Standard (WQS) of Bangladesh (Irrigation water and Drinking water)

Name of parameters/ Chemical/Mineral	Drinking	Irrigation
Aluminium (Al)	0.2 ppm	1.0 ppm
Ammonia (NH_3)	0.5 ppm	3.0ppm
Arsenic (As)	0.05 ppm	0.1 ppm
Bicarbonate	-	2.5 Me/L (200 ppm)
Biochemical Oxygen Demand (BOD)	0.2 ppm	10 ppm or below
Boron (B)	1.0 ppm	2 ppm
Cadmium (Cd)	.005 ppm	0.1 ppm
Calcium (Ca)	75 ppm	NYS

Name of parameters/ Chemical/Mineral	Drinking	Irrigation
Chemical Oxygen Demand (COD)	4 ppm	NYS
Chloride (Cl)	150-600 ppm	600 ppm
Coliform (faecal)	0 n/100 ml	10 n/100 ml
Coliform (Total)	0 n/100 ml	1000 ppm or below
Copper (Cu)	1 ppm	3 ppm
Dissolved Oxygen (DO)	6 ppm	4.5 - 8 ppm
Electrical Conductivity (EC)	600-1000 μs/cm	1200 μs/cm
Hydrogen ion Concentration (pH)	6.5-8.5	6.0-8.5
Iron (Fe)	0.3-1.00 ppm	1-2 ppm
Lead (Pb)	0.05 ppm	0.1 ppm
Magnesium (Mg)	30-50 ppm	NYS
Manganese (Mn)	0.1 ppm	5 ppm
Mercury (Hg)	0.001 ppm	.01 ppm
Nickel (Ni)	0.1 ppm	0.5 ppm
Nitrate (NO_3)	10 ppm	10 ppm as N_2
Nitrite (NO_2)	<1 ppm	NYS
Phosphate (PO_4)	6 ppm	10 ppm
Phosphorus (P)	0	15 ppm
Potassium (K)	12 ppm	NYS
Selenium (Se)	0.01 ppm	0.05 ppm
Silver (Ag)	0.02 ppm	NYS
Sodium (Na)	200 ppm	NYS
Sodium Absorption Ratio (SAR)	-	23
Sulfate (SO_4)	400 ppm	1000 ppm
Suspended Solid (SS)	10 ppm	NYS
T. Alkalinity	100 (WHO)/120 (USPHS)	-
T. Hardness	200-500 mg/l	-
Temperature	20^0-30^0C (50^0F)	20^0-30^0C (50^0F)
Tin (Sn)	2 ppm	NYS
Total Dissolved Solid (TDS)	1000 ppm	2100 ppm
Zinc (Zn)	5 ppm	10 ppm

Source: (Bangladesh Gazette Notification, 1997).

Arsenic

Arsenic is a chemical element that has the symbol As and atomic number 33. Arsenic was first written about by Albertus Magnus (Germany) in 1250. Its Atomic Mass is 74.92. Its Ionic charge is 3^-. Three metalloidal forms of arsenic with different crystal structures are found free in nature (the minerals arsenic sensu stricto and the much rarer arsenolamprite and pararsenolamprite), but it is more commonly found as arsenide and arsenate compounds. Several hundred such mineral species are known. Arsenic and its compounds are used as pesticides, herbicides, insecticides and various alloys.

The most common oxidation states for arsenic are -3 (arsenides: usually alloy-like intermetallic compounds), +3 (arsenates(III) or arsenites, and most organoarsenic compounds), and +5 (arsenates(V): the most stable inorganic arsenic oxycompounds). Arsenic is known to cause arsenicosis due to its manifestation in drinking water, "the most common species being arsenate [$HAsO_4^{2-}$; As (V)] and arsenite [H_3AsO_3 ; As(III)]". The ability of arsenic to undergo redox conversion between As(III) and As(V) makes its availability in the environment possible.

Arsenic compounds are water soluble and thus contamination of water may occur. Most of the arsenic found in water derives from geological formations, industrial discharges, mining operations, the use of arsenical insecticides and from the combustion of fossil fuels. Arsenic occurs naturally in rocks, soil, water, air, plants and animals. It can be further released into the environment through natural activities such as volcanic action, erosion of rocks and forest fires or through human actions. Approximately 90 percent of industrial arsenic in the U.S. is currently used as a wood preservative, but arsenic is also used in paints, dyes, metals, drugs, soaps and semi-conductors. High arsenic levels can also come from certain fertilizers and animal feeding operations. Industry practices such as copper smelting, mining and coal burning also contribute to arsenic in our environment.

Iron

Iron is the fourth most abundant element by weight in the earth's crust. Iron in groundwater is normally present in the soluble ferrous (Fe^{++}) form. It is easily oxidized to the insoluble ferric (Fe^{+++}) state upon exposure to air. Irrigation limit for Iron is 2-3 ppm. Iron in water may be present in varying quantities depending upon the geological area and other chemical components of the water sources. Ferrous (Fe^{++}) and ferric (Fe^{+++}) ions are the primary forms of concern in the aquatic environment. Other forms may be in either organic or inorganic wastewater streams. The ferrous form can persist in water void of dissolved oxygen and usually originates from groundwater wells. Black or brown swamp waters may contain iron concentrations of several mg/l in the presence or absence of dissolved oxygen, but this iron form has little effect on aquatic life. The current aquatic life standard is 1.0 mg/l based on toxic effects.

Iron in a soluble (ferrous) form may create emitter clogging problems at concentrations as low as 0.3 mg/l. Dissolved iron may precipitate out of the water due to changes in temperature or pressure in response to a rise in pH, exposure to air or through the action of bacteria.

Temperature

Temperature of water is a very important factor for aquatic life. It controls the rate of metabolic and reproductive activities. Temperature also affects the concentration of dissolved oxygen and can influence the activity of bacteria and toxic chemicals in water. Colorado Department of Public Health and Environment-Water Quality Control Division (CDPHE-WQCD) regulations (5 CCR 1002-31) state that waters classified as "Class 1 Cold Water Aquatic Life" should never have temperatures exceeding 20°C, while waters classified as "Class 1 Warm Water Aquatic Life" should never have temperatures exceeding 30°C. These regulations also state that temperature for these classes shall maintain a normal pattern of diurnal and seasonal fluctuations with no abrupt changes and shall have no increases in temperature of a magnitude, rate, and duration deemed harmful to the resident aquatic life. Generally, a maximum 3°C increase over a minimum of a 4-hr period, lasting 12 hrs maximum, is deemed acceptable.

pH

pH represents the effective concentration (activity) of hydrogen ions (H^+) in water. This concentration could be expressed in the same kind of units as other dissolved species, but H^+ concentrations are much smaller than other species in most waters. The activity of hydrogen ions can be expressed most conveniently in logarithmic units. pH is defined as the negative logarithm of the activity of H^+ ions: pH = -log $[H^+]$. According to Bangladesh environment conservation rules (1997), drinking water standard for pH is 6.5 -8.5 and 9irrigation water standard is 6-8.5

Hardness

Hardness is measure of polyvalent cations (ions with a charge greater than +1) in water. Hardness generally represents the concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, because these are the most common polyvalent cations. Other ions, such as iron (Fe^{2+}) and manganese (Mn^{2+}) may also contribute to the hardness of water but are generally present in much lower concentrations. Waters with high hardness values are referred to as "hard" while those with low hardness values are "soft".

Hardness mitigates metals toxicity because Ca^{2+} and Mg^{2+} help keep fish from absorbing metals such as lead, arsenic, and cadmium into their bloodstream through their gills. The greater the hardness the harder it is for toxic metals to be absorbed through the gills. When hardness equals alkalinity, the only cations present in significant concentrations in the water are calcium and magnesium. When hardness is greater than alkalinity, the waters may contain considerable amounts of other cations.

Calcium is an important component of plant cell walls and the shells and bones of many aquatic organisms. Low calcium levels can cause osmotic problems and affect shell or cuticle secretion in invertebrates (such as crayfish and snails). Magnesium is an essential nutrient for plants and a component of chlorophyll.

Alkalinity

Alkalinity is a measure of the buffering capacity of water, or the capacity of bases to neutralize acids. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. Alkalinity does not refer to pH, but instead refers to the ability of water to resist change in pH. The presences of buffering materials help neutralize acids as they are added to the water. These buffering materials are primarily the bases bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}), and occasionally hydroxide (OH^-), borates, silicates, phosphates, ammonium, sulfides, and organic ligands.

Alkalinity not only helps regulate the pH of a water body, but also the metal content. Bicarbonate and carbonate ions in water can remove toxic metals (such as lead, arsenic, and cadmium) by precipitating the metals out of solution. Above pH 8.3, alkalinity is mostly in the form of carbonate (CO_3^{2-}); below 8.3, alkalinity is present mostly as bicarbonate (HCO_3^-).

Nitrogen

Nitrogen is required by all organisms for the basic processes of life to make proteins, to grow, and to reproduce. Nitrogen is very common and found in many forms in the environment. Inorganic forms include nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), and nitrogen gas (N_2). Organic nitrogen is found in the cells of all living things and is a component of proteins, peptides, and amino acids. Nitrogen is most abundant in Earth's environment as N_2 gas, which makes up about 78 percent of the air we breathe. Nitrogen is recycled continually by plants and animals. This recycling of nitrogen through the environment is called the "nitrogen cycle."

Most organisms (including humans) can't use nitrogen in the gaseous form N_2 for their nutrition, so they are dependent on other organisms to convert nitrogen gas to nitrate, ammonia, or amino acids. "Fixation" is the conversion of gaseous nitrogen to ammonia or nitrate. The most common kind of fixation is "biological fixation" which is carried out by a variety of organisms, including blue-green algae, the soil bacteria Azobacter, and the association of legume plants and the bacteria Rhizobium. Additionally, nitrogen can be fixed by some inorganic processes. For example, "high-energy fixation" occurs in the atmosphere as a result of lightning, cosmic radiation, and meteorite trails.

Completing the nitrogen cycle, nitrates are reduced to gaseous nitrogen by the process of "denitrification." This process is performed by organisms such as fungi and the bacteria Pseudomonas. These organisms break down nitrates to obtain oxygen.

Ammonia

Ammonia, another inorganic form of nitrogen, is the least stable form of nitrogen in water. Ammonia is easily transformed to nitrate in waters that contain oxygen and can be transformed to nitrogen gas in waters that are low in oxygen. The dominant form depends on the pH and temperature of the water. The reaction between the two forms is shown by this equation:

$$NH_3 + H_2O = NH_4^+ + OH^-$$

The form of ammonia changes easily when pH changes. As pH increases, H^+ concentration decreases, and OH^- concentrations increase. This makes the equation above move left, increasing the amount of aqueous NH_3. When the pH is below 8.75, NH_4^+ predominates. At pH 9.24, about half of aqueous NH_3 is transformed to NH_4^+. Above pH 9.75, NH_3 predominates (Hem, 1985). Unionized ammonia (NH_3) is much more toxic to aquatic organisms than the ammonium ion (NH_4^+).

Toxic concentrations of ammonia in humans may cause loss of equilibrium, convulsions, coma, and death. Ammonia concentrations can affect hatching and growth rates of fish; changes in tissues of gills, liver, and kidneys may occur during structural development.

Phosphorus

Phosphorus is a nutrient required by all organisms for the basic processes of life. Phosphorus is a natural element found in rocks, soils and organic material. Phosphorus clings tightly to soil particles and is used by plants, so its concentrations in clean waters are generally very low. However, phosphorus is used extensively in fertilizer and other chemicals, so it can be found in higher concentrations in areas of human activity. Many seemingly harmless activities added together can cause phosphorus overloads.

Phosphorus in natural waters is usually found in the form of phosphates (PO_4^{-3}). Phosphates can be in inorganic form (including orthophosphates and polyphosphates) or organic form (organically-bound phosphates). Organic phosphate is phosphate that is bound to plant or animal tissue. Organic phosphates are formed primarily by biological processes. They are contributed to sewage by body waste and food residues, and also may be formed from orthophosphates in biological treatment processes or by receiving water biota. Organic phosphates may occur as a result of the breakdown of organic pesticides which contain phosphates. They may exist in solution, as loose fragments or in the bodies of aquatic organisms.

Inorganic phosphate is phosphate that is not associated with organic material. Types of inorganic phosphate include orthophosphate and polyphosphates. Orthophosphate is sometimes referred to as "reactive phosphorus". Orthophosphate is the most stable kind of phosphate, and is the form used by plants. Orthophosphate is produced by natural processes and is found in sewage. Polyphosphates (also known as metaphosphates or condensed phosphates) are strong complexing agents for some metal ions. Polyphosphates are used for treating boiler waters and in detergents. In water, polyphosphates are unstable and will eventually convert to orthophosphate.

Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate.

In freshwater of lakes and rivers, phosphorus is often found to be the growth-limiting nutrient, because it occurs in the least amount relative to the needs of plants. If excessive amounts of phosphorus and nitrogen are added to the water, algae and aquatic plants can be produced in large quantities. When these algae die, bacteria decompose them, and use up oxygen. This process is called entrophication. Dissolved oxygen concentrations can drop too low for fish to breathe, leading to fish kills. The loss of oxygen in the bottom waters can free phosphorus previously trapped in the sediments, further increasing the available phosphorus.

Total Solids

The term "total solids" refers to matter suspended or dissolved in water or wastewater and is related to both specific conductance and turbidity. Total solids (also referred to as total residue) are the term used for material left in a container after evaporation and drying of a water sample. Total Solids includes both total suspended solids, the portion of total solids retained by a filter (usually with a pore size of 0.45 micrometers), and total dissolved solids, the portion that passes through a filter (American Public Health Association, 1998).

Total solids can be measured by evaporating a water sample in a weighed dish, and then drying the residue in an oven at 103 to 105° C. The increase in weight of the dish represents the total solids. Instead of total solids, laboratories often measure total suspended solids and/or total dissolved solids

Total Suspended Solids

Total Suspended Solids (TSS) is solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.

High TSS can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis slows down. Reduced rates of photosynthesis causes less dissolved oxygen to be released into the water by plants. If light is completely blocked from bottom dwelling plants, the plants will stop producing oxygen and will die. As the plants are decomposed, bacteria will use up even more oxygen from the water. Low dissolved oxygen can lead to fish kills. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight.

The decrease in water clarity caused by TSS can affect the ability of fish to see and catch food. Suspended sediment can also clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. When suspended solids settle to the bottom of a water body, they can smother the eggs of fish and aquatic insects, as well as suffocate newly hatched insect larvae. Settling sediments can fill in spaces between rocks which could have been used by aquatic organisms for homes

High TSS in a water body can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water. These pollutants may attach to sediment particles on the land and be carried into water bodies with storm water. In the water, the pollutants may be released from the sediment or travel farther downstream (Federal Interagency Stream Restoration Working Group, 1998).

High TSS can cause problems for industrial use, because the solids may clog or scour pipes and machinery.

Total Dissolved Solids

Total Dissolved Solids (TDS) are solids in water that can pass through a filter. TDS is a measure of the amount of material dissolved in water. This material can include carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. A certain level of these ions in water is necessary for aquatic life. Changes in TDS concentrations can be harmful because the density of the water determines the flow of water into and out of an organism's cells (Mitchell and Stapp, 1992). However, if TDS concentrations are too high or too low, the growth of much aquatic life can be limited, and death may occur.

Similar to TSS, high concentrations of TDS may also reduce water clarity, contribute to a decrease in photosynthesis, combine with toxic compounds and heavy metals, and lead to an increase in water temperature .

TDS is used to estimate the quality of drinking water, because it represents the amount of ions in the water. Water with high TDS often has a bad taste and/or high water hardness, and could result in a laxative effect.

Sodium

Due to its effect on the soil and plant, sodium is considered to be one of the major factors governing water quality. The Sodium ion is ubiquitous in water owing to the high solubility of its salts and the abundance of mineral deposits.

Sodium Absorption Ratio

The SAR indicates relatively activity of the sodium ions in exchange reactions with the soil. Most normal soils of arid regions have calcium and magnesium as

$$SAR = \frac{Na}{\left[\frac{Ca + Mg}{2}\right]^{0.5}}$$

the principal cat-ions. Sodium Absorption Ratio (SAR) indicates the relative activity of the Sodium ions in exchange reactions with the soil. Irrigation water with a high SAR value will cause the soil to tighten up.

SAR Values

0 -10	-	Water is excellent
10 -18	-	Good
18 -28	-	Fair
Beyond 28 -		Poor

Magnesium

The most important qualitative criteria are the Mg content of the irrigation water, calculated by the formula:

$$MR = 100\left[\frac{Mg}{Ca + Mg}\right]$$

High Mg adsorption affects the soil unfavorably: a harmful effect on soils appears when the above ratio exceeds 50.

Calcium

There are three principal sources of calcium in natural water;

1. Limestone

2. Gypsum

3. Calcium carbonate

Limestone is soluble in water to the extent of 13 ppm. If carbon dioxide is present, the solubility may increase to 1000 ppm. Gypsum ($CaSO4$) is soluble to the extent of 200 ppm and Calcium Chloride is so highly soluble as to render water unfit as beverage long before saturation is reached.

Electrical Conductivity

It is the reciprocal of the electrical resistivity. Quantitatively the electrical resistivity is the resistance, in ohms, of the conductor, metallic or electrolytic, which is one cm long and has a cross- sectional area of 1 sq cm. It is used as a measure of the quality of the water. Acceptable limit for drinking water is 600-1000μs/cm and for irrigation is 1200μs/cm.

Zinc

Zinc most commonly enters the domestic water supply from deterioration of galvanized iron and dezincification of brass. Zn in water also may result from industrial waste pollution. It is an essential and beneficial element in human growth. Concentration above 5 mg/l can cause bitter astringent taste and opalescence in alkaline water. Bangladesh standard is 5.0 ppm (drinking) and 10.0 ppm (irrigation).

Boron

Boron may occur naturally in some waters or may find its way into a water course through cleaning compounds and industrial waste effluents. Sea water contains 5 mg/l (approx.) of boron. Although it is essential for plant growth, boron in excess of 2.0 mg/l in irrigation water is deleterious to certain plants. It does not affect the physical and chemical properties of soil, but at high concentrations it affects the metabolic activities of the plant. Some plants may be affected adversely by concentration as low as 1.0 mg/l. On the other hand for the most tolerant crop a concentration of boron exceeding 4 mg/l is considered unsafe.

2.4 Population Affected by Arsenic Contamination

The most commonly reported symptoms (offen referred to as arsenicosis) of chronic arsenic exposure are hyperpigmentation (dark spots on the skin), hypopigmentation (white spot on the skin) and Keratosis (skin hardens and develops raised wart-like nodules). Sometimes hyperpigmentation and hypopigmentation are commonly refferd to as melanosis. Arsenic also causes skin cancer, internal cancer and wide range of other health problems like abdominal pain, nausea, vomiting, diarrhea, anemia. The population of arsenic affected population country wide in Bangladesh during 2000 is shown the below table

Total population		Population Exposed to As> 0.05 ppm	% of Population Exposed to As>0.05ppm
Urban	28451940	3463533	12.17
Roral	102798723	27411552	26.67
Total	131250663	30875085	23.52

Source : BADC, Water quality report, 2004-07.

Estimation of Population exposed to arsenic concentration above the Bangladesh drinking water standard of 0.05 mg/l vary from about 20 million to over 36 million (DPHE/BGS/ MML 1999; Begum, 2001) . According to DPHE/BGS (2001) 35 million people of Bangladesh are exposed to an arsenic contamination in drinking water exceeding the national standard of 50 μg/l and 57 million people exposed to a concentration in exceeding 10μg/l, the standard of the World Health Organization

In the 1980's and 1990's, Bangladesh made enormous strides in supplying its population with drinking water through the provision of shallow tubewells. This resulted in Bangladesh achieving a coverage rate of 97% of the population will access to an improved water source and a significant reduction in diarrhoeal disease (Yu et al. 2003) estimated that consumption of contaminated water continues, the prevalance of arsenicosis and skin cancer in Bangladesh will be approximately 2,000,000 and 1,000,000 cases per year respectively and the incidence of death from cancer induced by arsenic will be approximately 3,000 cases per year. In a survey conducted in 270 villages of Bangladesh more than 7000 arsenicosis patients have been identified (Rahman et. al. 2000). In the nationwide screening program carried out by the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP, 2005) over 66 million people of every household of 270 arsenic- affected upazilas were sueveyed for arsenicosis patients. A total of 38,430 arsenicosis patients were identified in this survey. While the results from this survey are currently being analyzed results from previous surveys show poor correlation between the percentage of contaminated groundwater in a particular area and density of patients (BGS/DPHE, 2001).

Arsenic conamination of groundwater has appeared to be a serious public health problem in Bangladesh. Arsenic is a compound which is toxic to human body. Its toxicity is more than four times higer than that of the toxic trace element mercury(Hg) . Some effects of regular drinking arsenic contaminated water having arsenic concentration and beyond acceotable limit are very much significant. The women suffering from arsenic diseaes are worst victims. Affected young women are often compelled to stay unmarried. Affected married women are no longer considered acceptable as wives due to skin lesions and sent back to their parents with children, thereby unaffected parents and children are also suffering socially with the affected females. Above all, social life of the people is being jeopardized by the evil curse of arsenic contamination. According to the World Health Organisation, "In Bangladesh, West Bengal (India) and some other areas, most drinking-water used to be collected from open dug wells and ponds with little or no arsenic but with contaminated water transmitting diseases such as diarrhoea, dysentery, typhoid, cholera and hepatitis. Programmes to provide 'safe' drinking-water over the past 30 years have helped to control these diseases but in some areas they have had the unexpected side-effect of exposing the population". WHO has defined the areas under threat: Seven of the nineteen districts of West Bengal have been reported to have ground water arsenic concentrations above 0.05 mg/L. The total population in these seven to another health problem districts is over 34 million, with the number using arsenic-rich water is more than 1 million (above 0.05 mg/L). That number increases to 1.3 million when the concentration is above 0.01 mg/L.

2.5 Arsenic Contamination in Ground water in Bangladesh

Higher levels of arsenic tend to be found more in ground water sources than in surface water sources (i.e., lakes and rivers) of drinking water. Ground water contaminated by arsenic was first discovered by the Department of Public Health Engineering (DPHE) at Chaptai Nowabgonj in late 1993 following reports of elevated levels of arsenic in ground water of the adjoining areas of India. Further testing in 1995 and 1996 showed that contamination extended across large parts of southern and western Bangladesh. The demand on ground water from municipal systems and private drinking water wells may cause water levels to drop and release arsenic from rock formations. Compared to the rest of the United States, western states have more systems with arsenic levels greater than EPA's standard of 10 parts per billion (ppb). Parts of the Midwest and New England have some systems whose current arsenic levels are greater than 10 ppb, but more systems with arsenic levels that range from 2-10 ppb. While many systems may not have detected arsenic in their drinking water above 10 ppb, there may be geographic "hot spots" with systems that may have higher levels of arsenic than the predicted occurrence for that area.

Among the natural sources, arsenopyrite (FeAsS) is the most common arsenic bearing mineral. In addition, many sulfide minerals, especially pyrite (FeS_2 is found to be rich in arsenic. Chowdhury et.al (1998) reported presence of arsenic-rich pyrite in a number of arsenic affected districts in West Bengal, India. In Bangladesh two most probable (natural) sources responsible for arsenic contamination of ground are: (i) arsenopyrite or arsenic-rich pyrite, and (ii) arsenic-rich iron of hydroxides.

2.6 Arsenic in Food Production

Arsenic contamination of soil can occur as a result of both natural and anthropogonic activity. At present the use of As contaminated ground water for irrigation in Bangladesh, India and Vietnam is raising concerns. As can react with and become retained by the solid phase of the soil, be volatilisded into the atmosphere as a result of various biological transformations, be taken up by plants, be leached out of the spoil in groundwater and be washed out by rain water and flood. As contaminated soil is the potential for arsenic to be leached through the soil into groundwater. There are many reports of As movement down through the soil profile following the use of As containing herbicides and pesticides. In-organic arsenic is more mobile than organic arsenic and thus poses greater problems by leaching into surface water and groundwater (NCCR,1978). In a recent study conducted by Bangladesh University of Engineering & Technology and United Nations University (Ahmed et al, 2003) on Bangladesh shows that:

- Arsenic content of sediment of the Jamuna-Padma-Meghna rivers system varioes from 1.0 to 6.5 mg/kg depending on particle size of the sediment.
- Arsenic builds up in the top soil when irrigated with arsenic contaminated water and maintain a decline profile of depth.
- Arsenic content of agricultural soils increase during irrigation with contaminated water but it is reduced during post irrigation period probably by leaching with with flood/rain water and/or methylation process to the level of background concentration.
- Arsenic content of soil does not build up to a critical level that affects growth of crops.

Presence of Arsenic in soil or soil solution or water cause adverse effect on growth and yield.

Human activities are another source of arsenic in soils. Arsenic may accumulate in soil through use of arsenical pesticides, application of fertilizers, irrigation water and dust from the burning of fossil fuels, and disposal of industrials and animal wastes. The anthropogenic dispersion pattern, the distance from the pollution sources and the intensity of the human activity are the most important parameters that influence arsenic concentration in soil. An industrial aerosol also causes soil contamination that emitted from various industrials plant. Bituminous and sub-bituminous coals have been used as domestic fuels and by coal burning power stations, and soil may contaminated by fly ash. Application of the material over a long period of time can lead to accumulation of arsenic in soil with consequent effects on plants. Excess amount of arsenic in soil is potentially toxic plants and animals (Zou. 1986).

2.7 Summary

Over the last few decades food production in the country has increased significantly mainly due to the success of the irrigated agriculture during the dry season. Agriculture during the dry season is heavily dependent on groundwater; According to recent (BADC, 2007), a total of 1202728 shallow tubewells and 29177 deep tubewells were used for irrigation during 2006 boro season. The contribution of groundwater irrigation covers about 80% of the total irrigated area and shallow tubewell irrigation alone covers about 65.46% of total irrigated area. Since we are increasingly depending on shallow aquifer for irrigation water which is more contaminated by arsenic. However, Correlation of as between Water quality parameters and soil nutrients is becoming a common phenomenon for safety food production in many regions of the country. If arsenic concentration in irrigation water 100ppb and if total of 1000 mm of irrigation water is provided to the field over the dry season (e.g. for boro rice), then this I kg of arsenic per hectare of irrigated land each year, close to 1000 metric tons arsenic could be cycled each year through irrigation water (Shaha, 2004). Arsenic in irrigation water poses a potential challenge to the agriculture sector. Since more and more areas experiencing such problems with passage of time, this phenomenon may have an adverse impact on the food production and the lives of farmers. Thus it is very important to identify areas which may experience problems related to arsenic contaminated groundwater and retention of arsenic by soil and uptake by plants, and appropriate understanding the relation of arsenic between soil and water parameters and its possible long term impacts. Wheat and rice is very important crop in Bangladesh. Bangladeshi's are not only dependant on rice but also on wheat. That's why it is very important to know Arsenic concentration of both wheat and rice.

CHAPTER 3
DATA COLLECTION AND METHODOLOGY

3.1 Introduction

Ground water irrigation greatly increased agricultural production in Bangladesh, thus food security is heavily dependent on ground water irrigation. In many areas of Bangladesh, concentration of arsenic in soil is going to increasing due to use of arsenic affected ground water for irrigation during the dry season. In order to asses the contamination of agricultural land by arsenic from irrigated water and find the possible correlation between arsenic and other important parameters both soil and water the primary and secondary data is collected from the study area. This Chapter presents the methodology adopted in this research work. It also describes sampling, data collection and analysis of the data.

3.2 Site Selection

It is showed that a significant number of irrigation wells in Jessore District conducted by BADC with arsenic above acceptable limit for irrigation. The food chain issue is becoming more and more important as there are increased evidence of arsenic buildup in crops and different types of vegetation, that's why in this study, Jessore district is selected. In Jessore district, Keshabpur, Jessore Sadar and Jhikorgacha Upazila are selected for this research work. The concentration of arsenic of 0.2 ppm was recorded in Samta village of Sharsha upazila of Jessore district in the STW which is source of irrigation. Thus a research site for Paddy and wheat was selected in that area. Arsenic and other important parameters level in irrigation water and top soil layer were measured from arsenic affected ground water of Keshabpur and Sharsha Upazila of Jessore district. In Jessore district, experiment with five wheat verities, namely Kanchan, Protiva, Gowrab, Sowrav and Shatabdi was conducted at Samta village following randomized block Design (RBD) with three replications for each variety. Fertilizer doses were selected from fertilizer recommendation guide (BARC, 1997).

Experiment with rice was also conducted during Rabi and Kharif season at the above location. During Rabi season a total of ten rice varieties were included in the experiment. The varieties are BR-3, BR-14, BR-16, BR-26, BR-28, BR-29, Minikat, Ratna, Jamaibabu and Kajallata. The fertilizers doses were selected from fertilizers were applied as used by the farmers. In Kharif II season, due to unavailable circumstances experiment with rice was not carried out following statistical design. However, four varieties of rice, namely Sharnalata, BR-10, BR-11 and BR- 30 were irrigated with single replication. In each sampling area, arsenic and iron concentration of irrigation water and arsenic concentration of soil in seven locations were measured in Environmental laboratory in BUET.

3.3 Sample Collection

3.3.1 Collection of water samples

Sixty five number of water samples were collected in pre-washed 500 ml plastic bottles, after running the well for at least 15 minutes. Water sample in bottle was acidified with 1 ml concentrated hydrochloric acid, which was later analyzed for dissolved arsenic and iron

3.3.2 Collection of soil samples

In order to estimate arsenic and iron level in the top soil layer of selected field irrigated by a particular irrigation well, soil core samples were collected from different location of the study area. In Bangladesh, depending on location, dry season irrigation for paddy commences sometime between the last week of December and the first week of February and continues about three to three and half months. In this study soil core samples were collected after the rainy season i.e. before beginning of the next irrigation season. Soil core samples were collected by a 37.5 mm diameter PVC pipe sampler inserting into the soil about 750 mm in height. A three pound by weight hammer was used to insert the pipe sampler to a depth of about 500 mm. After withdrawing the sampler along with the soil core, both the ends were sealed with tapes to reduce contact with air and transported to the laboratory.

3.3.3 Collection of paddy and wheat plant

Paddy and wheat plant samples were collected just at harvest time. Entire paddy and wheat plants (including roots) were collected. From every block design paddy and wheat plant samples were collected. A total of 10 paddy plant samples and 5 wheat plant samples were collected from the experiment field. It was showed that BR-28 and BR-29 are the predominant paddy varieties grown at the selected field sites.

3.4 Laboratory Analysis of Water and Soil Samples

3.4.1 Analysis of water samples

Water from acidified sampling bottles was used in the laboratory for analysis of arsenic and iron. Analysis of water samples was carried out following methods.

Analytical methods

In this study, arsenic concentration in water samples was measured with an AAS (Shimadzu, AAS6800) attached with a graphite furnace. Iron concentrations in the water samples were measured with flame emission atomic absorption spectrophotometer (Flame-AAS) using AAS (Shimadzu, AAS6800, and Japan). pH was measured using a pH meter (HACH), and conductivity with conductivity meter. Nitrogen-Nitrate, sulphate and phosphate were measured using field testing kits, US brands (Hach, LaMotte).

3.4.2 Analysis of soil samples

Digestion of soil sample

For determination of aqua-regia extractable arsenic, the selected soil sample was taken in an aluminum bowl and kept in an oven at 110° C for 24 hours. After drying for 24 hours, the sample was ground in a grinder. The grinded soil sample was digested with aqua-regia for extraction of metal ions. For digestion, 2.5 ml concentrated nitric acid and 7.5 ml concentrated hydrochloric acid were added to 5 gm grinded oven dried sample taken in a 500 ml volumetric flask. The sample was kept overnight in the flask and then it was heated to boiling for two hours. Afterwards distilled water was added up to the 500 ml graduation mark. The contents of the flask were stirred for 5 minutes, then cooled and finally filtered using a filter paper (0.45 micron). The filtrate was stored in a plastic bottle for analysis of arsenic using an AAS attached with a graphite furnace (Shimadzu AA6800).

3.4.3 Analysis of plant samples

Digestion of plant sample

At first the paddy and wheat plant samples were divided into three parts: 1) Root (2) Straw and (3) Grain. A number of similar but different digestion procedure are available in the literature (e.g. Bennet et al., 2000; Chen and Folt, 2000; Shimadzu AAS Cookbook, 1999). In this study Shimadzu AAS Cookbook was selected for digestion. Digestion procedure consists of the following steps:

1. Wash plant samples with distilled water
2. Divide the plant sample into parts (as described above)
3. Take weight of each part of the sample
4. Dry the sample at 65°C for 24 hours and take weight of the oven-dried sample.
5. Take approximately 0.5 gms of oven-dried sample in a volumetric flask and make it moist by adding a few milliliters of deionized water, then add 25 ml nitric acid to the flask and keep it overnight.
6. Heat the flask for two hours to boiling then after cooling add 10 ml of perchloric acid to the flask and heat again (to boiling) for one hour.
7. If color of the sample turns yellow, digestion is assumed to be complete.
8. If color of the sample turns dark, add 2 to 3 ml of nitric acid to the flask and apply heat; repeat the process untills the color turns yellow.

For chemical analysis Nitrogen was determined by Kjeldahl method, Phosphorus by colorometry, Potassium by flame photometry and Sulphur by turbidimetry. Arsenic content of digest sample was determined by Atomic Absorption Spectrophotometer (AAS). All the chemical analyses of paddy and wheat plant samples were carried out in the laboratory of the Department of Soil Science, Dhaka University. Samples for arsenic determination were digested in the laboratory of the Department of Soil Science, Dhaka University and measurements of arsenic contents were carried out in the laboratory of Survey and Monitoring Project, BADC.

3.4 Analysis of Data

From the compilation of test results computer analysis has been done with the use of relevant software (EXCEL and ORIGIN). The correlation co-efficient between arsenic and iron with sulphate and phosphate of water was determined with the use of Origin Software by Liner Fit Analysis.

The arsenic, iron, sulphate and phosphate concentration of the study area are shown in graph and map. Map was created using Arc View 3.3 software. A major obstacle in preparing a map using the data on water quality parameters was estimating GPS coordinates of the monitoring wells. The GIS Arc-View software uses data with geographically referenced position, Thus using GPS the positions of BADC monitoring wells are recorded to prepare `maps as accurately as possible. As, Fe, PO_4,, N-NO_3, Ca, Mg, N_2, range were divided into 5 groups: first group is within allowable limit of drinking set by who i.e. Arsenic up to 0.01 mg/l, Second group is over 0.01 mg/l and less or equal to 0.05mg/li.e., up to Bangladesh standard limit for Arsenic and the last group is Arsenic over 0.05 mg/l i.e., exceeding Bangladesh limit. Iron range were divided into four groups: first group is within allowable limited set by WHO i.e., iron up to 0.3 mg/1, second group is iron over 0.3mg/l and less or equal to 1.0 mg/l i.e., Bangladesh standard limit for iron. Third group is iron over 1.0 mg/l and less or equal to 5.0gm/l i.e., Iron may be considered as safe having no alternative source of suitable drinking water. The last group is iron exceeding 5.0mg/l, posing a potential threat to public health.

The correlation co-efficient of arsenic, iron, sulphate and phosphate concentration of tube wells of the districts: Jessore, Upazila: Jessore Sadar, Keshabpur and Jhikorgacha were determined. The correlation co-Efficient of arsenic and Fe both water and soil of Keshabpur thana of Jessore district was also calculated and shown in Tables. GIs based maps showing the correlation of soil and water parameters i.e. arsenic, iron, sulphate and phosphate of Keshabpur Upazila. Asses the contamination pf agricultural land by As, Fe from Irrigated water 3 Upazila was selected. From Keshabpur Upazila Soil and water is collected and As, Fe was measured. Only Keshabpur Upazila presented the As concentration of soil and prepare a map using Arc View GIS.

For chemical analysis of Nitrogen, Phosphorus, Potassium and Sulphur more widely used methods were followed. Nitrogen was determined by Kjeldahl method, Phosphorus by colorometry, Potassium by flame photometry and Sulphur by turbidimetry. Samples were digested with nitric acid and arsenic content of digest was determined by atomic absorption spectrophotometer. All the chemical analyses were carried out in the laboratory of the Department of Soil, Water and Environment of Dhaka University except arsenic determination. Samples for arsenic determination were digested in Dhaka University and measurements of arsenic contents were carried out in the laboratory of Survey and Monitoring Project, BADC, Sech Bhaban, Manik Mia Avenue

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Introduction

There are many parts of the world where the moisture available in the soil from rain or underground water. If water is polluted the plant even human being is affected by different disease. That's why quality of water should be ensured. Besides it is very much necessary to know quality of soil. In this chapter result of this study was briefly described. Arsenic, iron, sulphate and phosphate concentration of water samples of tube wells in Jessore Sadar, Keshabpur and Jhikorgacha upazila of Jessore district were analyzed. Arsenic and iron concentration of soil of Keshabpur and Sharsha Upazila were analyzed. Arsenic and nutrient concentration of rice and wheat were also analyzed of the Shamta village of Sharsha upazila of Jessore district.

4.2 Ground water Quality of Study Area

Jessore Sadar Upazila

Concentration of selected chemical constituents of ground water in Jessore Sadar upazila samples were collected from the irrigation wells of 20 locations in Jessore Sadar upazila are shown in table 4.1. From Table 4.1, it can be seen that about 20 sample, only two sample's arsenic concentrations are unsuitable for irrigation, four samples of iron concentration are unsuitable for irrigation. The maximum concentration of arsenic, iron, sulphate and phosphate are 0.70, 7.00, 17.80, 25.20 and 8.31 mg/l respectively. It is shown that there is no significant co-relation between these parameters i.e arsenic concentration is not dependent on iron concentration and other parameters. Similarly iron concentration is not dependent other important parameters of water. Relation of important parameters of water that is arsenic, iron, sulphate and phosphate is not regular. About 20 samples arsenic concentration is high in Ghuni mouza, iron concentration is high kachua mouza, sulphate concentration is high in Hapania mouza and phosphata concentration is high in jhaudiaj mouza. Analysis of the data and subsequent summarization show that the values of the water quality parameters such as arsenic, iron, sulphate and phosphate concentration in different selected tube wells in Jessore Sadar upazila are different. Moreover there are no variations of any water quality parameters with depth.

Table- 4.1: Water quality parameters of Sadar upazila

Source of Water	Depth (ft)	District	Upazila	Union	Mouza	As (ppm)	Fe (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)
DTW	258	Jessore	Jessore sadar	Deara	Arenda	0.00	0.20	0.99	6.21
HTW	70	Jessore	Jessore sadar	Deara	Arenda	0.03	0.60	0.50	5.60
DTW	261	Jessore	Jessore sadar	Norendrapur	Balorampur	0.01	0.50	0.50	4.20
HTW	162	Jessore	Jessore sadar	Norendrapur	Gopalpur	0.01	0.60	0.50	4.60
DTW	262	Jessore	Jessore sadar	Ramnagar	Kazipur	0.01	7.00	1.49	4.70
STW	140	Jessore	Jessore sadar	Ramnagar	Kazipur	0.00	3.40	0.99	5.20
DTW	260	Jessore	Jessore sadar	Habibpur	Hapania	0.20	2.83	0.99	25.20
STW	130	Jessore	Jessore sadar	Habibpur	Hapania	0.03	0.35	0.50	17.40
DTW	288	Jessore	Jessore sadar	Fatepur	Vaina	0.00	0.00	1.49	1.70
STW	60	Jessore	Jessore sadar	Fatepur	Vaina	0.00	2.00	1.49	1.70
DTW	271	Jessore	Jessore sadar	Arabpur	Sujalpur	0.00	0.60	0.50	0.40
STW	60	Jessore	Jessore sadar	Arabpur	Sujalpur	0.03	0.80	0.90	0.96
DTW	236	Jessore	Jessore sadar	Kachua	Kachua	0.01	0.40	0.25	2.00
STW	90	Jessore	Jessore sadar	Kachua	Kachua	0.03	7.00	0.50	2.18
DTW	311	Jessore	Jessore sadar	Paurosova	Kharki	0.00	3.30	2.17	0.70
STW	165	Jessore	Jessore sadar	Paurosova	Kholadanga	0.03	0.50	1.98	0.40
DTW	297	Jessore	Jessore sadar	Basundia	Ghuni	0.70	0.50	2.48	0.40
Pond	15	Jessore	Jessore sadar	Basundia	Bhariab	0.00	0.00	0.50	0.90
DTW	288	Jessore	Jessore sadar	Churamal	Jhaudiaj	0.00	0.50	5.36	12.70
STW	170	Jessore	Jessore sadar	Churamal	Jhaudiaj	0.03	0.50	8.31	3.90

Figure 4.1 shows the relation between arsenic and iron in Jessore sadar upazila. From Figure 4.1 found that among 20 sample of water, there is no significant

relationship between arsenic and iron. Some water samples have high arsenic value but those samples are free from iron. Figure 4.2 shows the relation between arsenic and sulphate. The relation is not co-operative. It seems that arsenic is slightly dependent with sulphate. But it is not regular correlation. Figure 4.3 shows the relation between arsenic and phosphate. The overall correlation between arsenic and iron, arsenic and sulphate, arsenic and phosphate (of the same tube well water) indicates a poor correlation (R=0.071, 0.037 and 0.09 respectively). It may be noted that there exists is no significant correlation among the water quality parameters of ground water (Ferdausy, S.M. 2005).

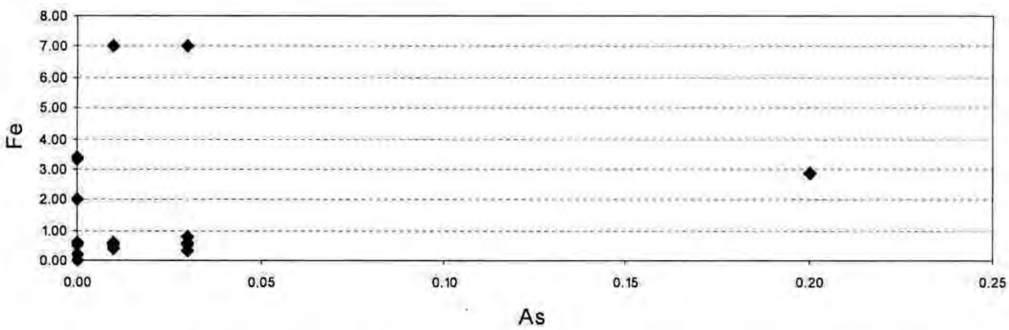


Figure 4.1: Relationship between arsenic and iron in Sadar upazila

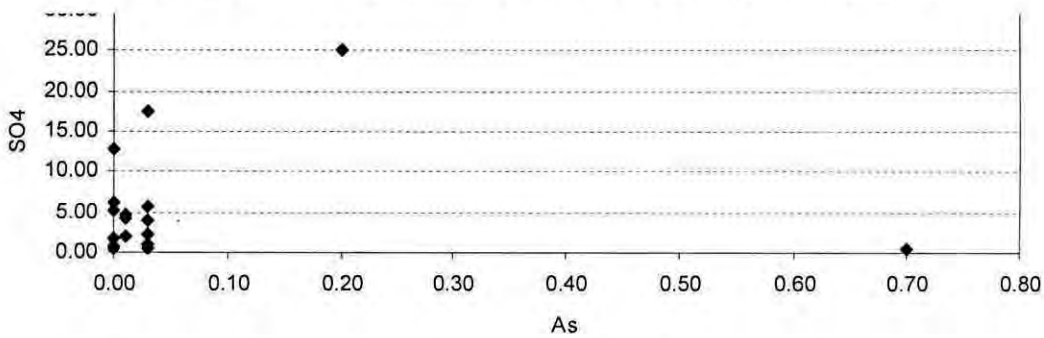


Figure 4.2: Relationship between arsenic and sulphate in Sadar upazila

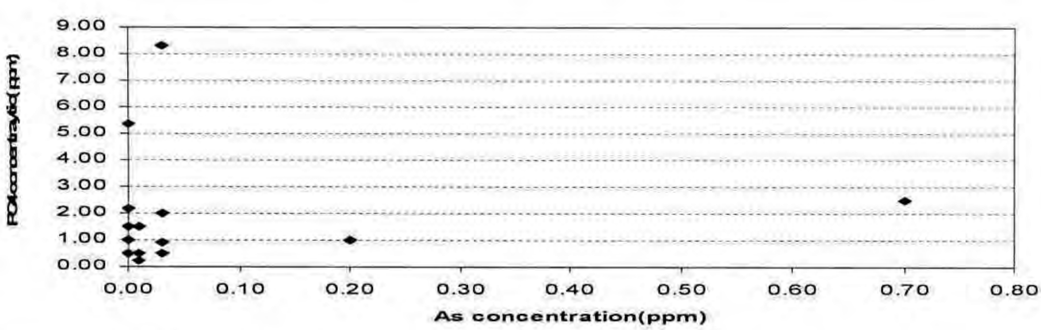


Figure 4.3: Relationship between arsenic and phosphate in Sadar upazila

Jhikorgacha upazila

Different water quality parameter's concentrations are shown in table 4.2. From Table 4.2 it can be seen that about 14 sample, only arsenic concentration of 1 sample is unsuitable for irrigation, 4 sample of iron concentration are unsuitable for irrigation. The maximum concentration of arsenic, iron, sulphate and phosphate are 0.30, 3.30, 15.80 and 2.98 mg/1 respectively. It is shown that there is no significant co-relation between these parameters i.e arsenic concentration is not dependent on iron concentration and other parameters. Similarly iron concentration is not dependent other important parameters of water. Relation of important parameters of water that is arsenic, iron, sulphate and phosphate is not regular. About 14 samples arsenic concentration is high in Bittachra mouza, iron concentration is high Mohispara mouza, sulphate concentration Bittachra mouza and phosphata concentration is high in Bishohori mouza. Analysis of the data and subsequent summarization show that the values of the water quality parameters such as arsenic, iron, sulphate and phosphate concentration in different selected tube wells in Jessore Sadar upazila are different. Moreover there are no variations of any water quality parameters with depth.

Table: 4.2 Water quality parameters of Jhikorghacha upazila

Source of Water	Depth (ft)	District	Upazila	Union	Mouza	As (ppm)	Fe (mg/L)	SO4 (mg/L)	PO4 (mg/L)
DTW	288	Jessore	Jhikarghaca	Sankarpur	Shahkarpur	0.00	0.60	4.60	0.90
STW	120	Jessore	Jhikarghaca	Sankarpur	Shahkarpur	0.01	0.00	5.80	0.99
DTW	290	Jessore	Jhikarghaca	Navaran	Sharifpur	0.03	0.00	6.90	0.90
STW	120	Jessore	Jhikarghaca	Navaran	Sharifpur	0.01	2.40	9.80	0.37
DTW	288	Jessore	Jhikarghaca	Nirbaskhola	Asingri	0.01	1.20	7.30	0.90
STW	110	Jessore	Jhikarghaca	Nirbaskhola	Asingri	0.03	1.40	7.80	0.74
DTW	280	Jessore	Jhikarghaca	Panisara	Taura	0.01	0.40	4.00	2.17
STW	120	Jessore	Jhikarghaca	Panisara	Taura	0.03	2.00	10.80	2.79
DTW	280	Jessore	Jhikarghaca	Hazirbag	Mohispara	0.03	3.00	1.80	2.48
STW	120	Jessore	Jhikarghaca	Hazirbag	Mohispara	0.05	3.30	3.80	1.98
DTW	290	Jessore	Jhikarghaca	Gonganond	Bishohori	0.05	2.00	2.00	2.48
STW	145	Jessore	Jhikarghaca	Gonganond	Bishohori	0.01	1.00	1.50	2.98
DTW	248	Jessore	Jhikarghaca	Putkhali	Bittachra	0.01	2.40	11.40	1.40
STW	120	Jessore	Jhikarghaca	Putkhali	Bittachra	0.30	3.20	15.80	0.50

Figure 4.4, Figure 4.5 and Figure 4.6 shows the relation between arsenic and iron, relation between arsenic and sulphate, relation between arsenic and phosphate in Jhikorgacha upazila respectively. From those figures it is shown that there are no significant correlations among arsenic, iron, sulphate and phosphate in Jhikorgacha upazila. The overall correlation between arsenic and iron, arsenic and sulphate, arsenic and phosphate (of the same tube well water) indicates a poor correlation (R2=0.071, 0.037 and 0.09 respectively).

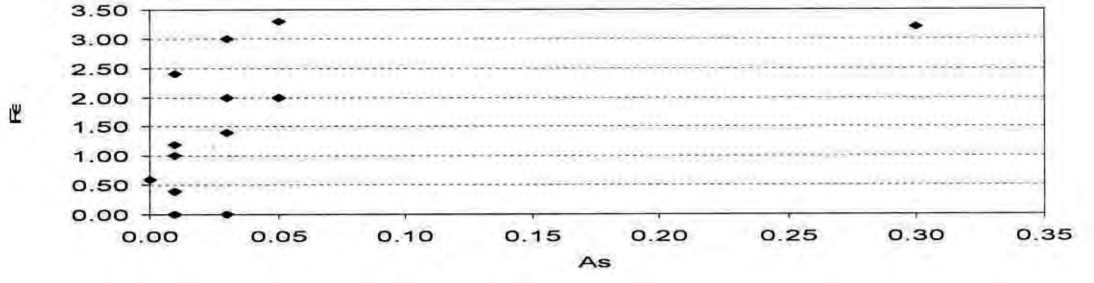


Figure 4.4: Relationship between arsenic and iron in Jhikorgacha upazila

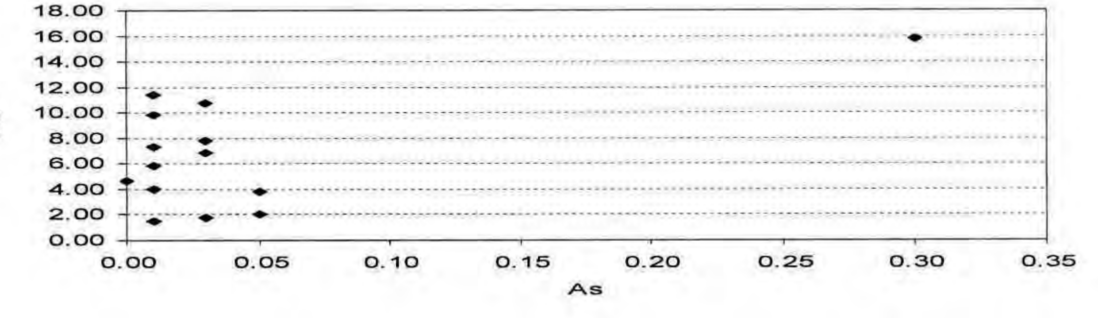


Figure 4.5 Relationship between arsenic and sulphate in Jhikorgacha Upazila

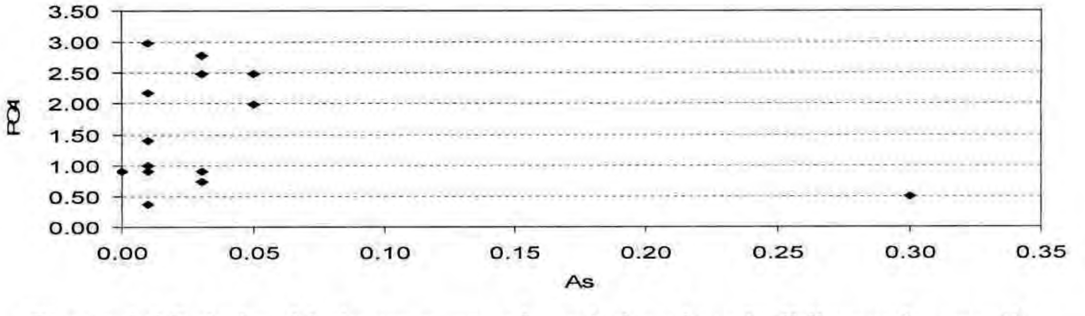


Figure 4.6 Relationship between arsenic and phosphate in Jhikorgacha upazila

Keshabpur upazila

Table 4.3 shows the concentration of ground water quality of different parameters in Keshabpur upazila about 30 samples. Arsenic concentration of 5 samples is unsuitable for irrigation and 1 sample of iron concentration are unsuitable for irrigation. The maximum concentration of arsenic, iron, sulphate and phosphate are 0.70, 3.00, 5.00, and 1.49 mg/l respectively. Figure 4.7 shows the relation between arsenic and iron in Keshabpur upazila. From this figure it is found that there is no significant co-relation between arsenic and iron in selected location in Keshabpur upazila. Similarly Figure 4.8 and Figure 4.9 show the relation between arsenic and sulphate, relation between arsenic and phosphate respectively. From those Figure it is shown that there is no significant relation among important parameters of water. Highest concentration of arsenic, iron, sulphate and phosphate was found in Pazia, and Sufalkati.

Table 4.3: Water quality parameters of Keshobpur upazila

Sl. No.	Union	Mouza	As (ppm)	Fe (mg/l)
1	Mozidpur	Pratappur	0.00	2.00
2	Pazia	Pazia	0.70	3.00
3	Gourighona	Gourigha	0.50	1.60
4	Sufalakati	Sufalkati	0.70	2.00
5	Bidyanan	Bidyanan	0.50	2.00
6	Bidyanan	Dobaria	0.30	2.01
7	Bidyanandakati	Burihati	0.03	0.16
8	Bidyanandakati	Burihati	0.03	6.98
9	Gaurighona	Bherchi	0.01	0.15
10	Gaurighona	Sannyasgachha	0.05	0.17
11	Keshabpur	Brahmakati	0.30	1.59
12	Keshabpur	Ramchandrapur	0.20	0.93
13	Majidpur	Bagdaha	0.03	0.20
14	Majidpur	Deuli	0.03	0.10
15	Mangalkot	Chagha	0.10	2.78
16	Mangalkot	Kedarpur	0.20	0.81
17	Panjia	Belkati	0.03	0.43
18	Panjia	Sagar Dattakati	0.03	0.13
19	Sagardari	Barihati	0.03	0.49
20	Sagardari	Barihati	0.05	0.94
21	Sufalakati	Hariaghop	0.03	0.63
22	Sufalakati	Narayanpur	0.03	0.14
23	Trimohini	Satbari	0.05	0.67
24	Trimohini	Satbari	0.03	0.09
25	Keshabpur	Altapol	0.17	3.90
26	Bidyanandakati	Burihati	0.04	5.25

Sl. No.	Union	Mouza	As (ppm)	Fe (mg/l)
27	Sagardari	Sagardari	0.31	4.15
28	Trimohini	Janpur	0.09	4.98
29	Magalkot	Magurkhali	0.17	3.93
30	Sufalakati	Kalicharanpur	0.00	0.27
31	Sufalakati	Kalicharanpur	0.00	0.03
32	Gaurighona	Bherchi	0.00	0.06

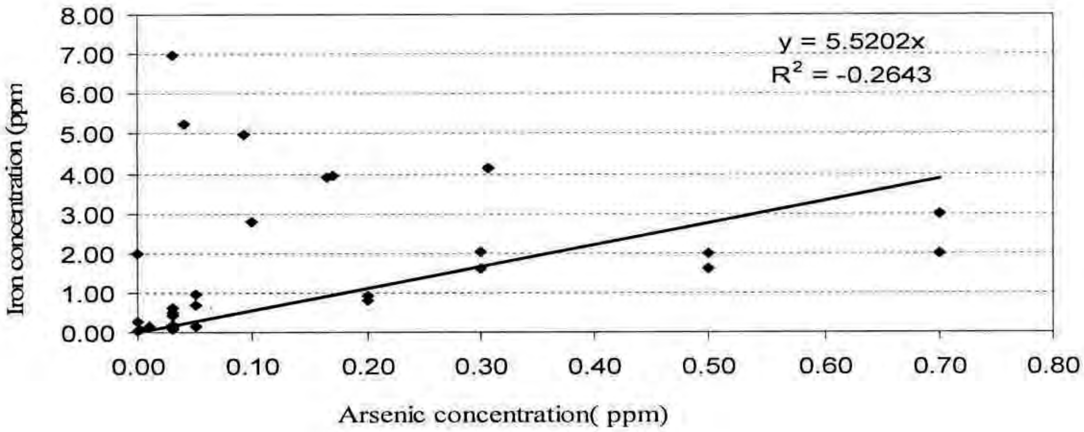


Figure 4.7: Relationship between arsenic and iron concentration in Keshabpur upazila

Analysis of the data and subsequent summarization show that the values of the water quality parameters such as arsenic, iron, sulphate and phosphate concentration in different selected tube wells in Keshabpur upazila are different. Moreover there are no variations of any water quality parameters with depth. Also it is shown that there are no significant correlations among arsenic, iron, sulphate and phosphate. The overall correlation between arsenic and iron, arsenic and sulphate, arsenic and phosphate (of the same tube well water) indicates a poor correlation

4.3 GIS Based Map of Arsenic, Iron, Sulphate and Phosphate of Water in Jhikorgacha, Keshabpur and Sadar Upazila of Jessore District

It is essay to understand for simply cope and compare different features based on their common field when we represent the data using geographic. By the tabulate form of data we can't understand the relation and general condition three or more fields at a time but using geographic map we can do this. From the Geo-graphic map of Keshabpur Upazila, it is found that arsenic value at Ghuni mouza of Basundia union is higher than another location, the other elements such as iron, sulphate and phosphate are not found in that particular area..

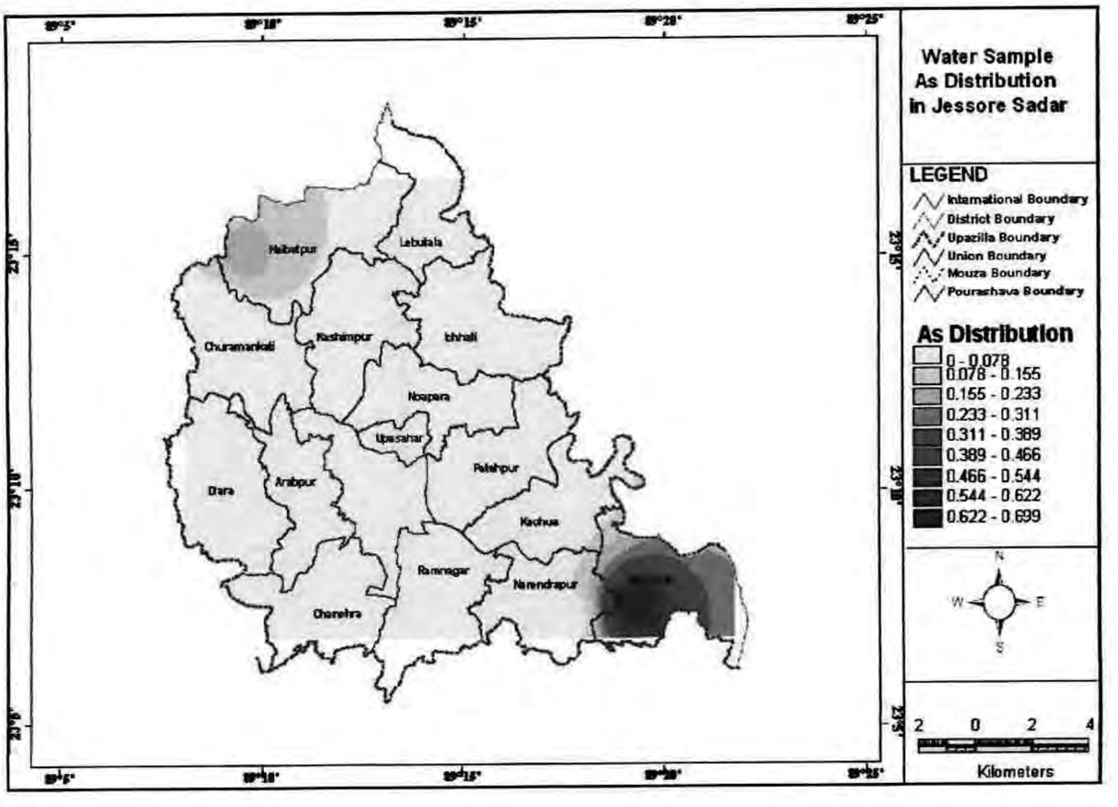


Figure 4.8: Arsenic concentration distributions in Sadar upazila

The Figure 4.8 shows the different formation of red color. Deep red color indicates the highest arsenic concentration of Jessore Sadar upazila which is found in Ghuni mouza of Basundia union. It is about 5% of total sample.

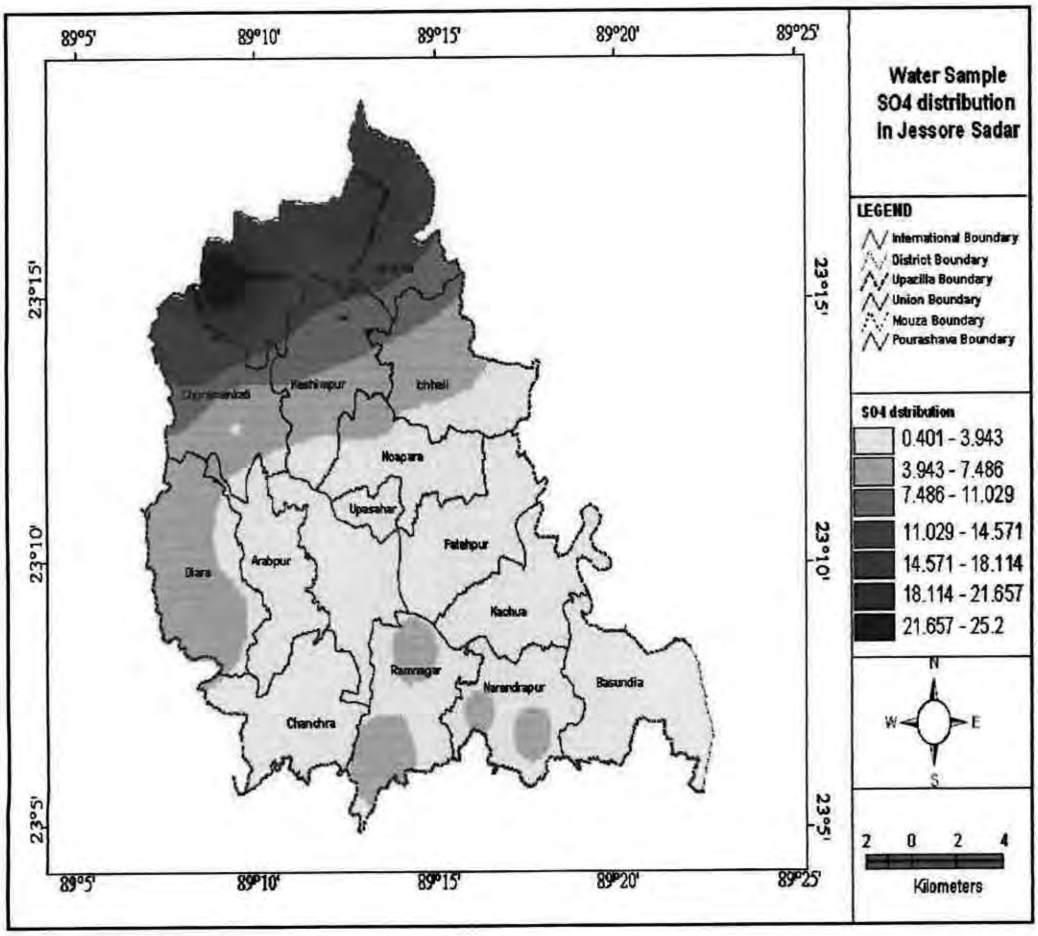


Figure 4.9 Sulphate concentration distribution in Sadar upazila

The Figure 4.9 shows the different formation of red color. Deep red color indicates the highest sulphate concentration of Jessore Sadar upazila which is found in Hapania mouza of Haibatpur union (14 ppm -25 ppm). It is about 10% of total sample. Slightly deep red color indicates the sulphate concentration range of 7.48 ppm to 11 ppm.

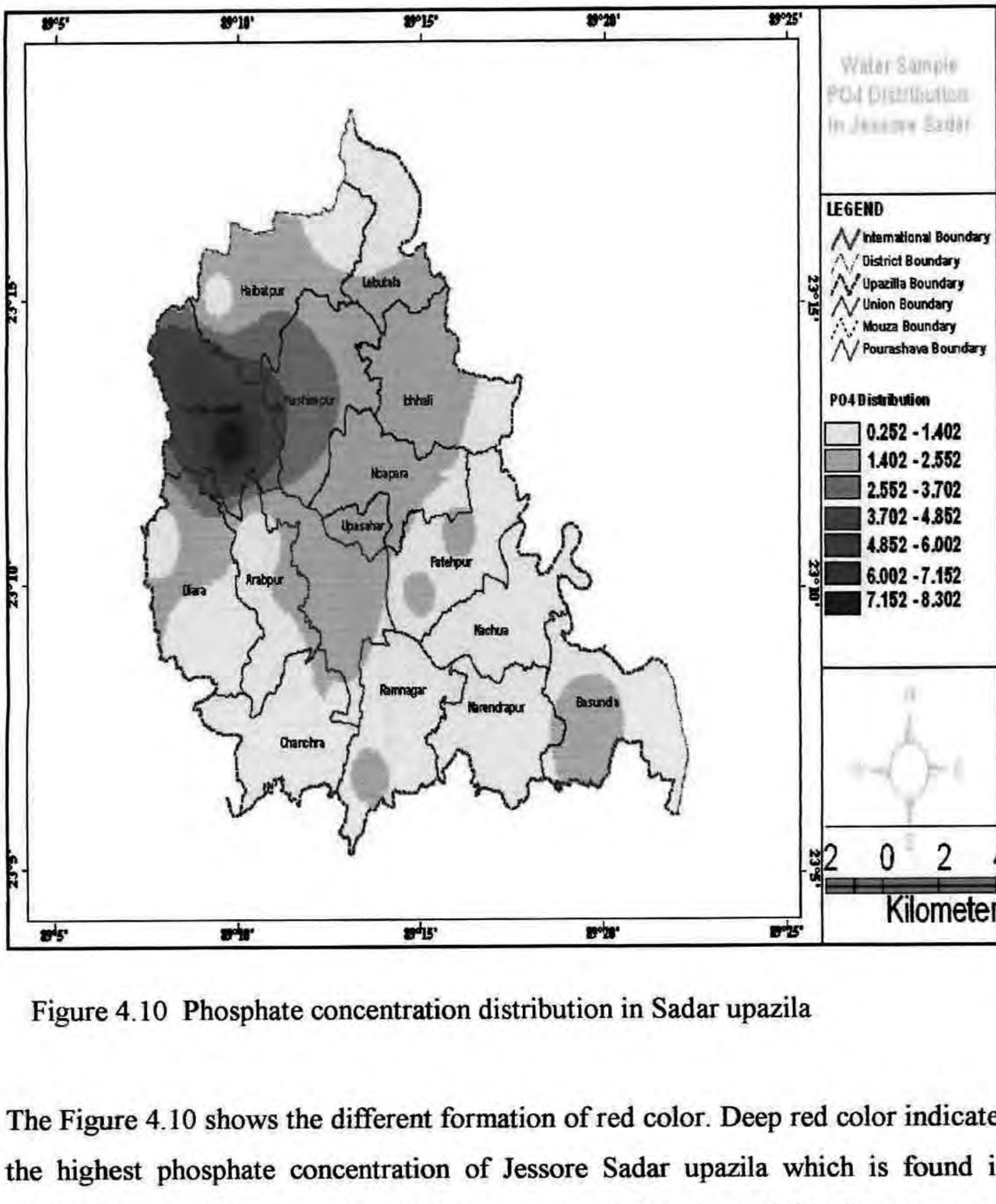


Figure 4.10 Phosphate concentration distribution in Sadar upazila

The Figure 4.10 shows the different formation of red color. Deep red color indicates the highest phosphate concentration of Jessore Sadar upazila which is found in Jhaudiaj mouza of Churamal union (6 ppm -8 ppm). It is about 10% of total sample. Slightly deep red color indicates the phosphate concentration range of 1 ppm to 3.7 ppm.

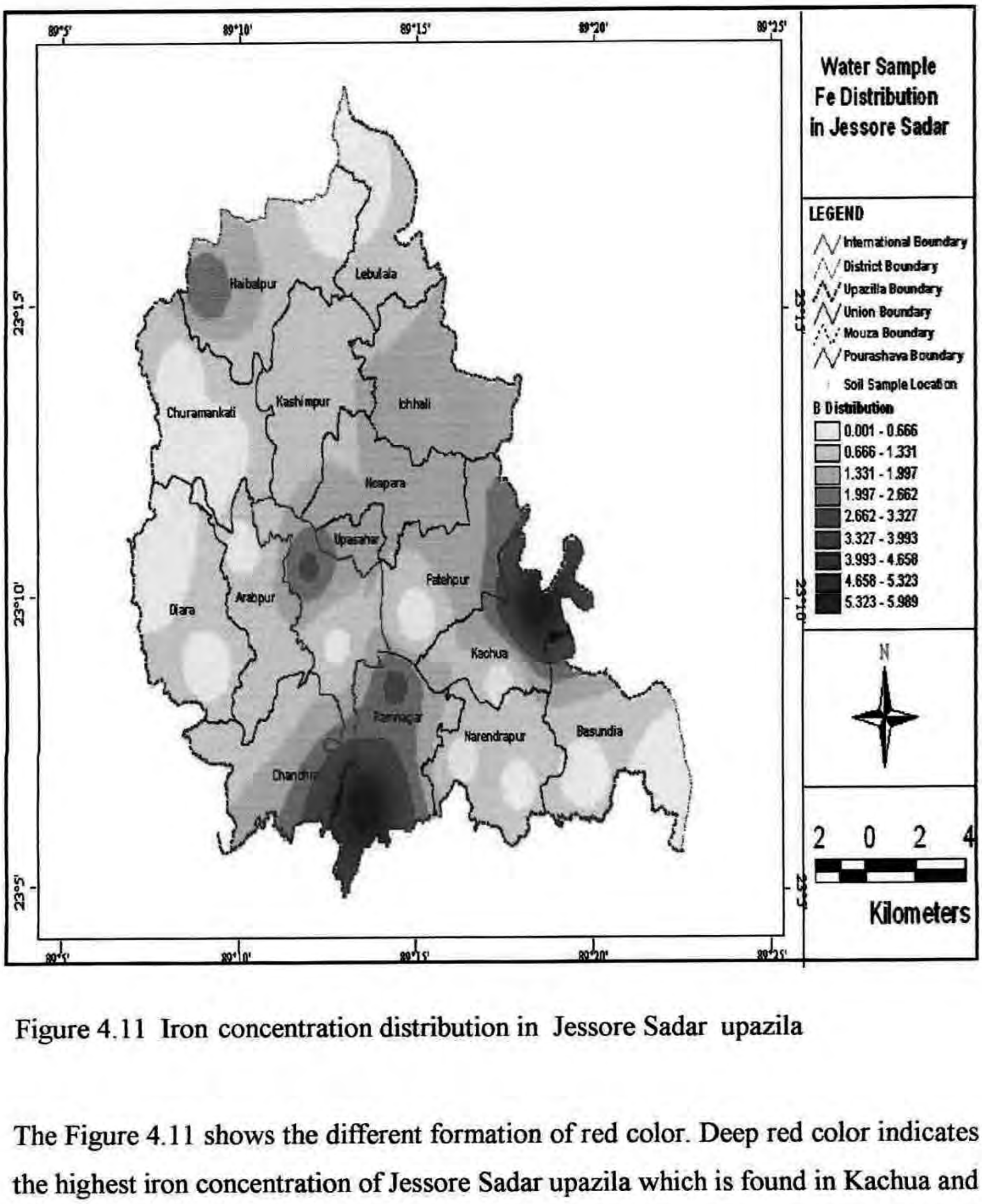


Figure 4.11 Iron concentration distribution in Jessore Sadar upazila

The Figure 4.11 shows the different formation of red color. Deep red color indicates the highest iron concentration of Jessore Sadar upazila which is found in Kachua and kajipur union (3.3 ppm to 5.9 ppm). It is about 10% of total sample. Slightly deep red color indicates the iron concentration range of 0.6 ppm to 2.6 ppm.

From the Figure 4.8, 4.9 4.10 and 4.11 showed that deep red color are found Ghuni union, Habipur union, Churamal union and Kachua union respectively. Therefore Geo-graphic map of Jessore Sadar upazila represents that highest concentration water quality parameters are not found in the same location. Thus it is revealed that there is no significant correlation among important water quality parameters such as arsenic, iron, sulphate and phosphate

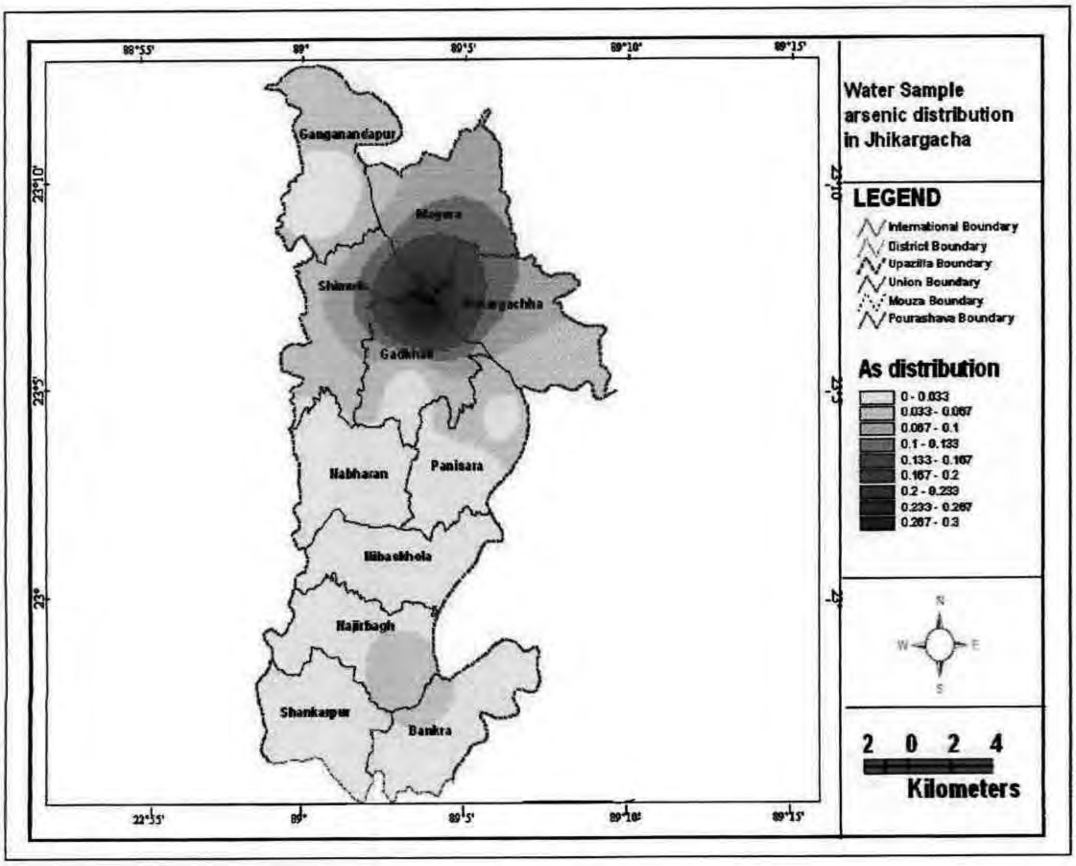


Figure 4.12 Arsenic concentration distribution in Jhikoagacha upazila

The Figure 4.12 shows the different formation of red color. Deep red color indicates the highest arsenic concentration of Jhikorgacha upazila which is found in Gadkhali union (0.1ppm to 0.3 ppm). It is about 5% of total sample. Slightly deep red color indicates the arsenic concentration range of .01 ppm to 0.06 ppm.

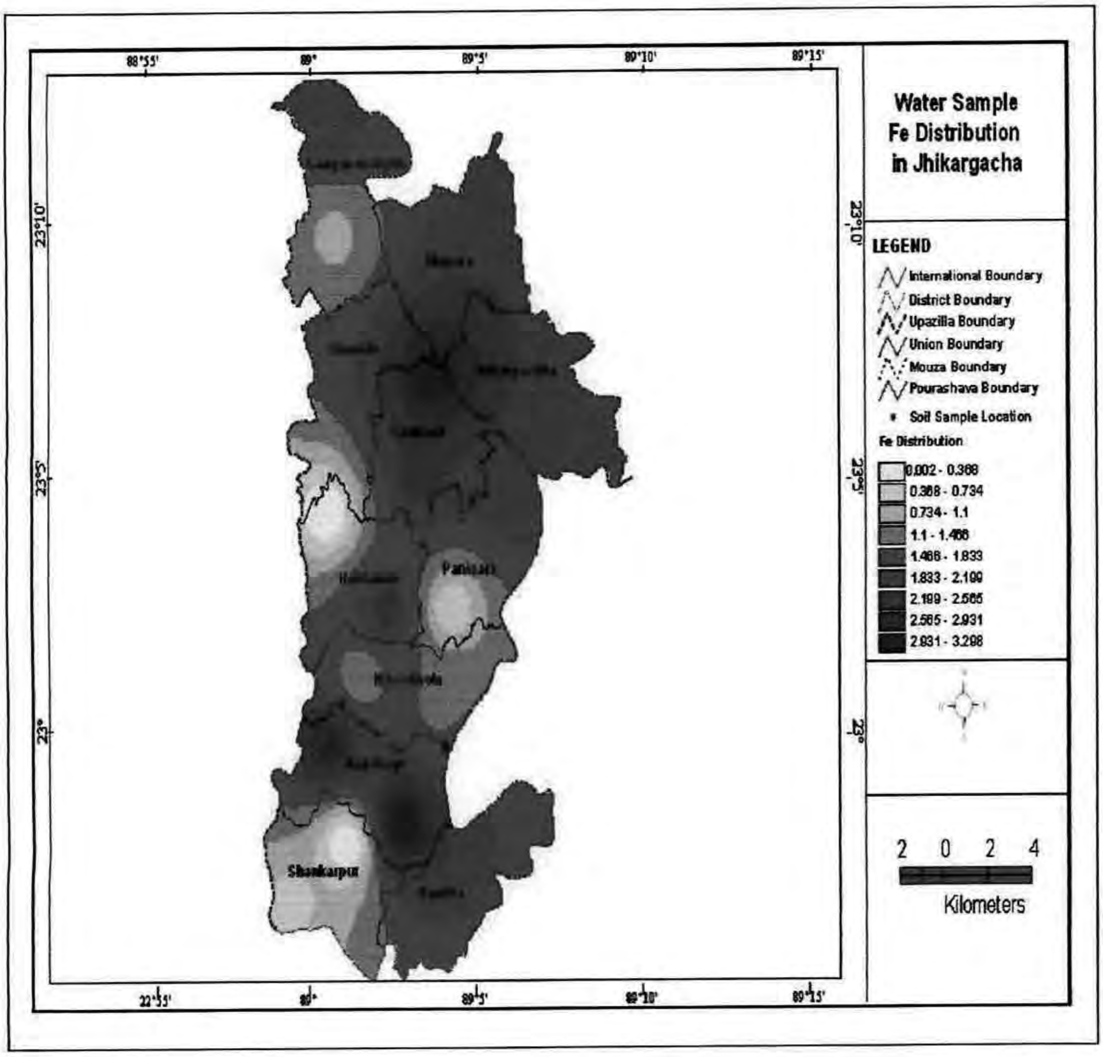


Figure 4.13 Iron concentration distribution in Jhikorgacha upazila

The Figure 4.13 shows the different formation of red color. Deep red color indicates the highest iron concentration of Jhikargacha upazila which is found in Hajirbag and bunkhail union (2.1ppm to 3.3 ppm). It is about 15% of total sample. Slightly deep red color indicates the iron concentration range of 1.1 ppm to 1.83 ppm

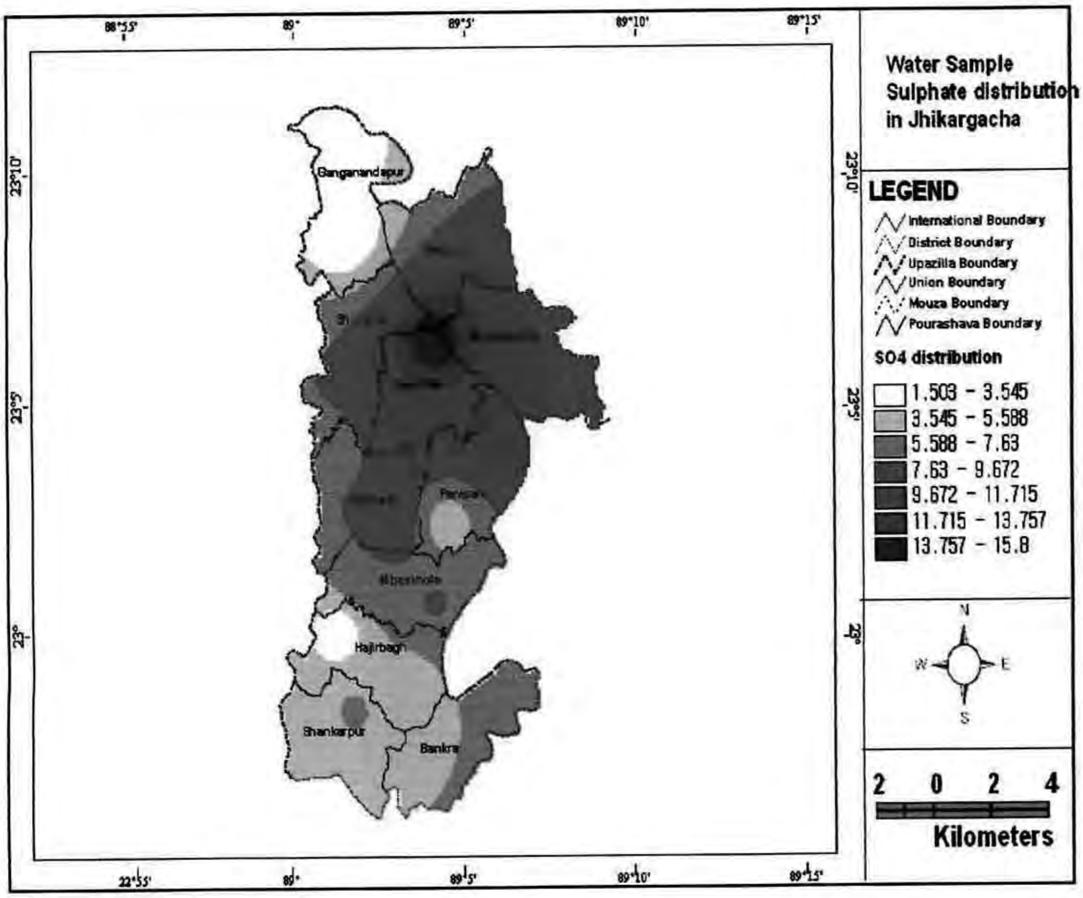


Figure 4.14 Sulphate concentration distribution in Jhikorgacha upazila

The Figure 4.14 shows the different formation of red color. Deep red color indicates the highest sulphate concentration of Jhikargacha upazila which is found in bunkhali union and panisara union (11.715 ppm to 15.8 ppm). It is about 10% of total sample. Slightly deep red color indicates the sulphate concentration range of 1.1 ppm to 1.83 ppm.

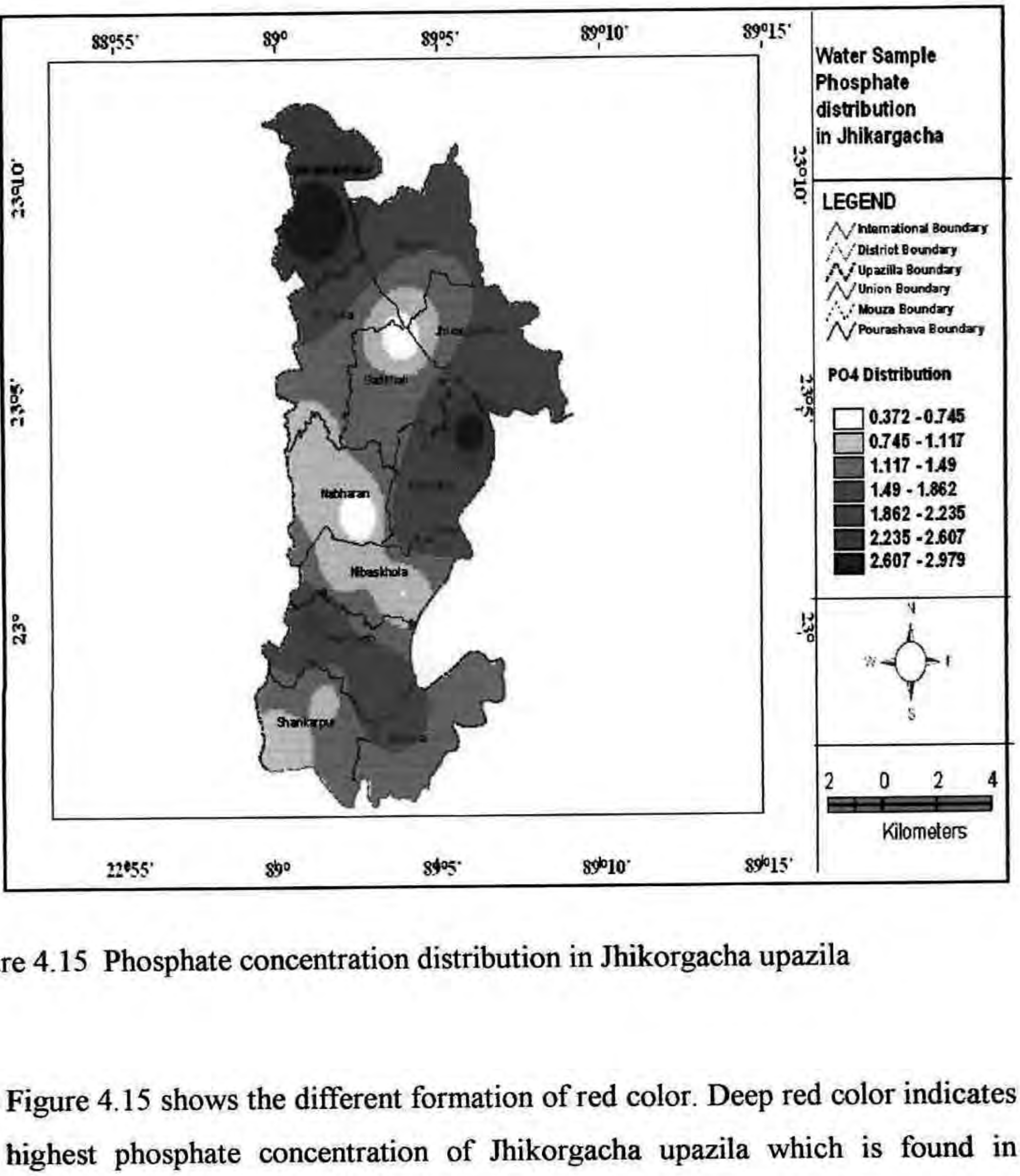


Figure 4.15 Phosphate concentration distribution in Jhikorgacha upazila

The Figure 4.15 shows the different formation of red color. Deep red color indicates the highest phosphate concentration of Jhikorgacha upazila which is found in Gonganond and panisara union (2.235 ppm to 2.979 ppm). It is about 10% of total sample. Slightly deep red color indicates the phosphate concentration range is lower than Gonanond and panisara union.

From the Figure 4.12, 4.13, 4.14 and 4.15 showed that deep red color are found Bunkhali union, Hajirbag union, Bunkhali union and Gongnanond union respectively. Therfore Geo-graphic map of Jhikorgacha upazila represents that highest concentration water quality parameters are not significantly found in the same location i.e among 14 location, arsenic, iron and sulphate are co-relatibe between one another but it is not regular.Thus it is revealed that there is no significant correlation among important water quality parameters such as arsenic, iron, sulphate and phosphate alltime. Co- relation depend on agricultural land's formation.

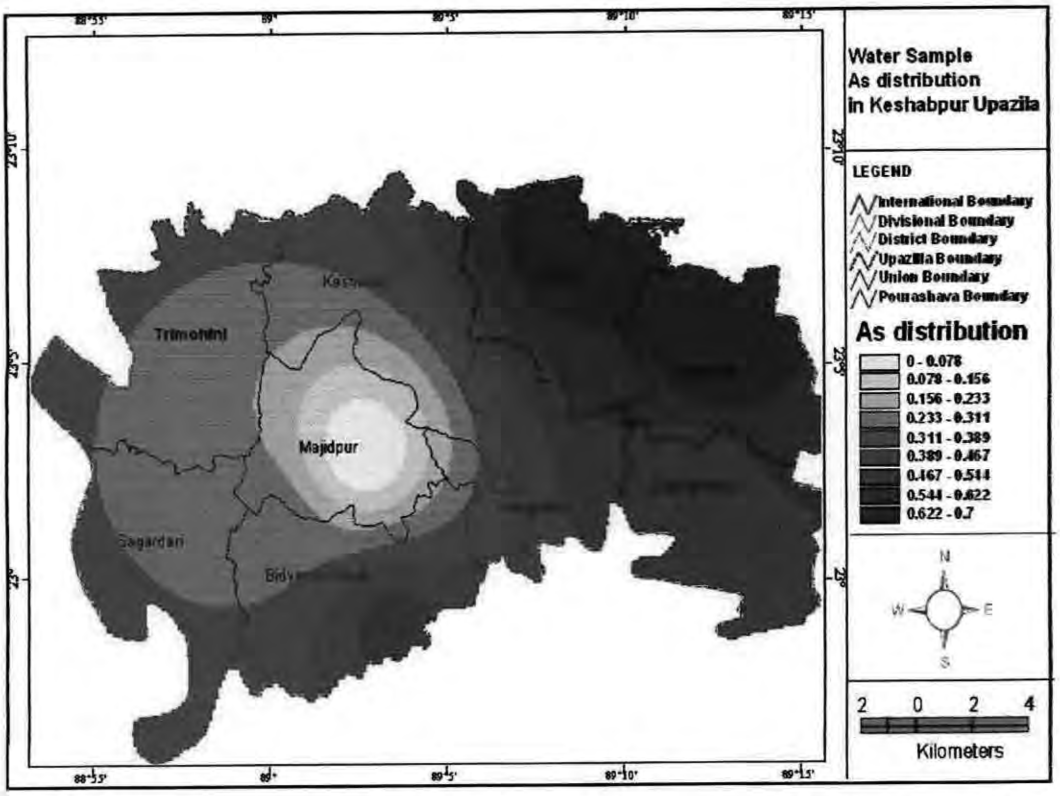


Figure 4.16 Arsenic concentration distribution in Keshabpur upazila

The Figure 4.16 shows the different formation of red color. Deep red color indicates the highest arsenic concentration of Keshabpur upazila which is found in Hajirbag and bunkhail union (2.1ppm to 3.3 ppm). It is about 15% of total sample. Slightly deep red color indicates the iron concentration range of 1.1 ppm to 1.83 ppm

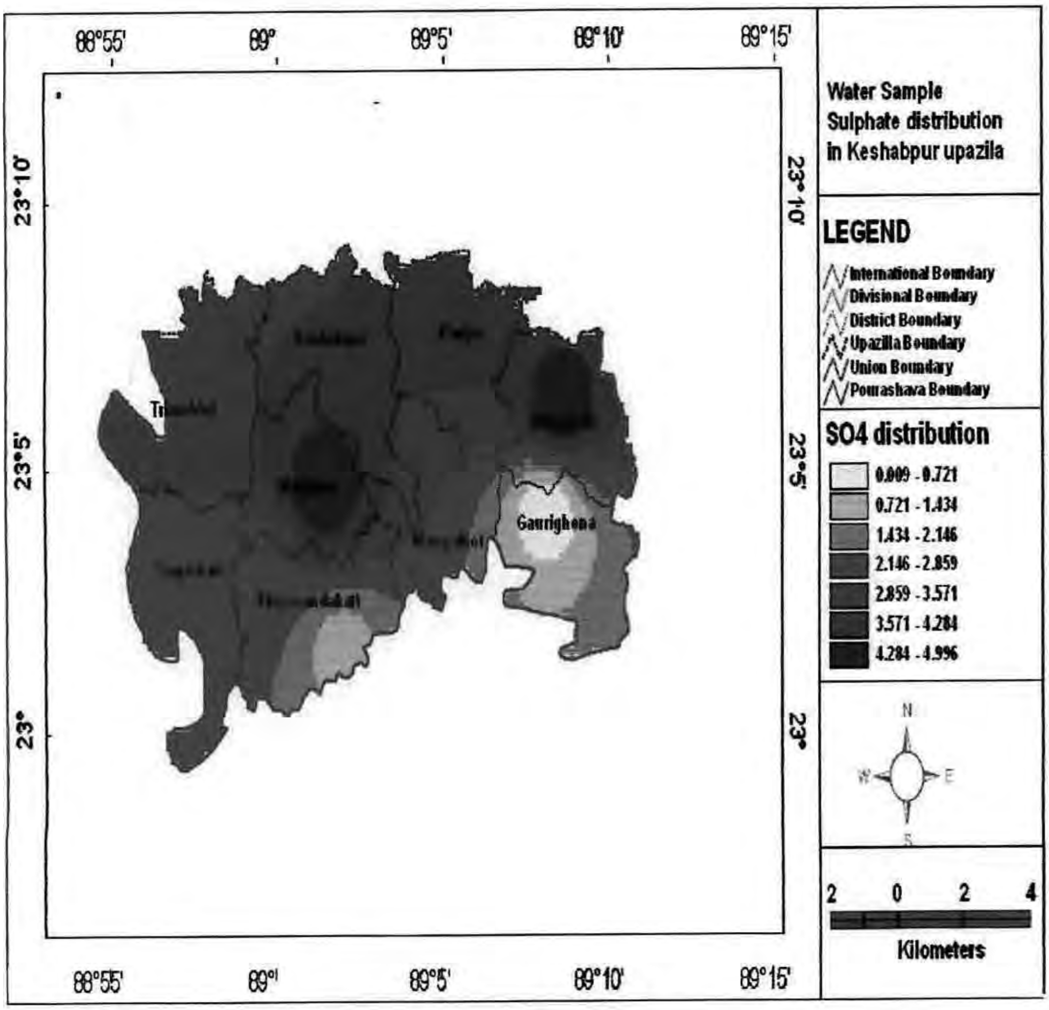


Figure 4.17 Sulphate concentration distribution in Keshabpur upazila

The Figure 4.17 shows the different formation of red color. Deep red color indicates the highest sulphate concentration of Keshabpur upazila which is found in Mozidpur and Sufalakati union. In case of Mozidpur union, where arsenic value is zero there sulphate value is high compare between another location/sample. Slightly deep red color indicates the sulphate concentration range o.721 ppm to 2.85 ppm

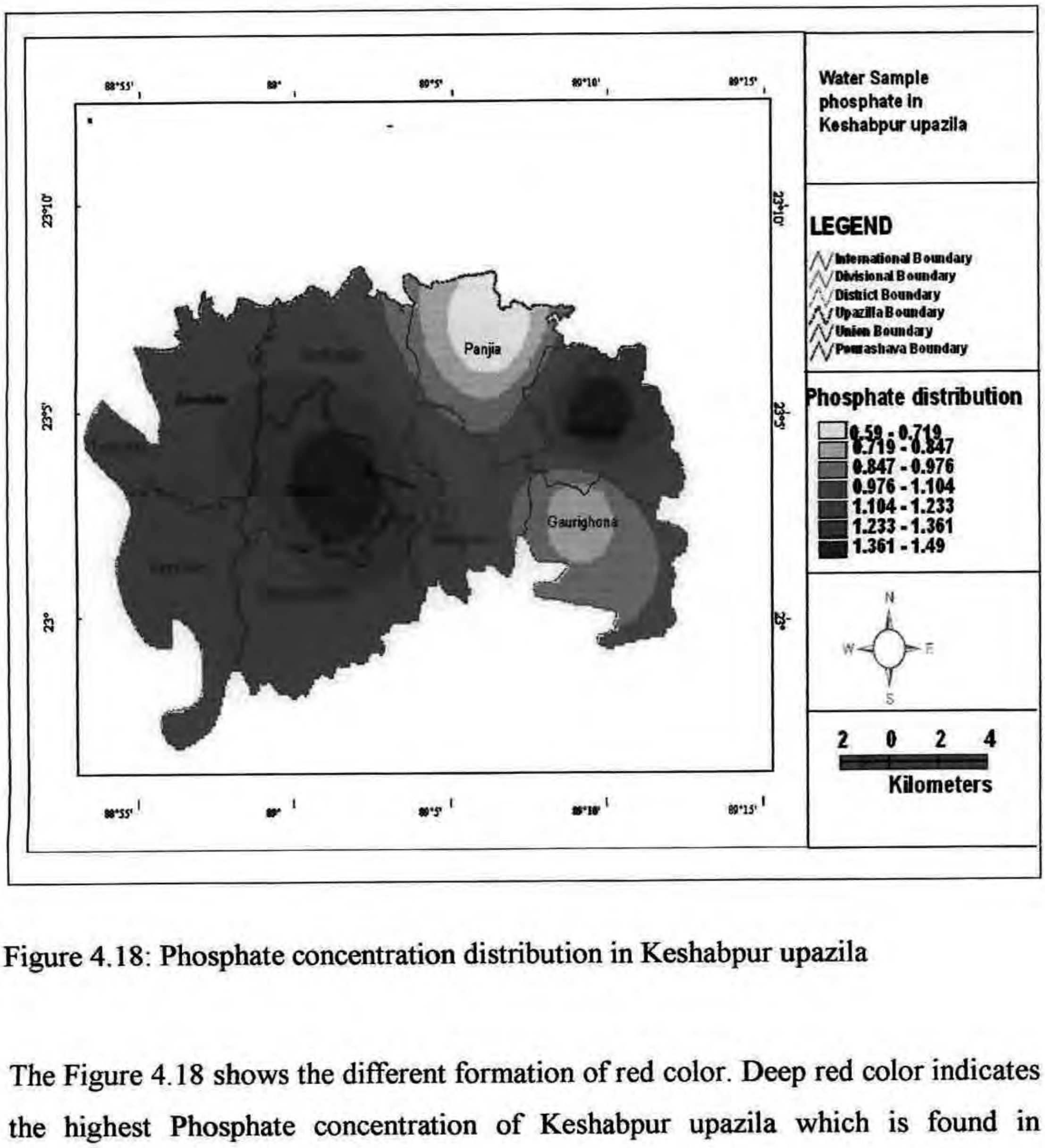


Figure 4.18: Phosphate concentration distribution in Keshabpur upazila

The Figure 4.18 shows the different formation of red color. Deep red color indicates the highest Phosphate concentration of Keshabpur upazila which is found in Mazidpur and Sufalakati union (1.49 ppm). It is about 10% of total sample. In case of Phosphate and sulphate of collected sample of Keshabpur upazila both are co-relative with one another. But there are not significant correlation between arsenic and phosphate. Slightly deep red color indicates the phosphate concentration range of 0.59 ppm to 1.1083 ppm.

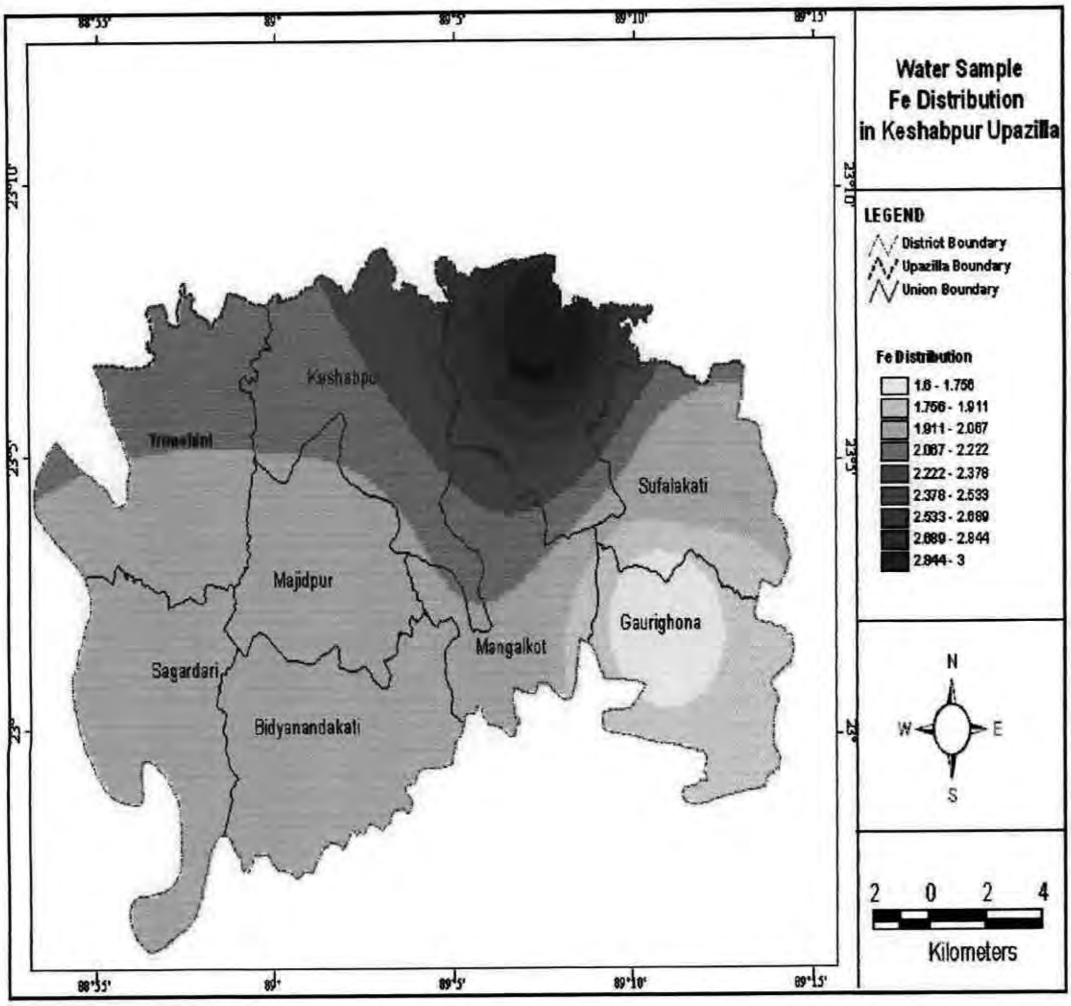


Figure 4.19: Iron concentration distribution in Keshabpur upazila

The Figure 4.19 shows the different formation of red color. Deep red color indicates the highest iron concentration of Keshabpur upazila which is found in Pazia union (3.00 ppm). Slightly deep red color indicates the iron concentration range of 1.0 ppm to 2.37 ppm.

From the Geo-graphic Figure 4.16, 4.17, 4.18 and 4.19 represents that highest concentration water quality parameters are not significantly found in the same location i.e among 6 location, arsenic, iron and sulphate are co-relative between one another but it is not regular. Thus it is revealed that there is no significant correlation among important water quality parameters such as arsenic, iron, sulphate and phosphate all time. Co- relation depends on agricultural land's formation.

4.4 Relation between Arsenic and Iron of Soil and Water in Keshabpur Upazila

Soil is the main media of crop production. In Bangladesh Soil is also affected by arsenic. It is found that clay fraction contained highest concentration arsenic, followed by silt and sand (Chowdhury, M.A.I, 2006). It is also observed that arsenic levels in the paddy field soils are quite dynamic. After the flood/rainy season and before beginning of the next irrigation season, arsenic levels in the top soil layer of paddy field decreases significantly and comes down to levels comparable to those found at the beginning of the previous season (Shaha, G.C, 2006). So it is very important to know the relation between Arsenic and Iron of Soil and Water. Soil absorb nutrient by water. So if water is polluted soil must be unsuitable for food production. Present of any chemical compounds in irrigation water are very strong reagent. The long term chemical effect of irrigation water is affected by soil and then plant absorbs the nutrient. So it is most important to know contamination of agricultural land by arsenic from irrigated water. In this study Keshabpur upazila is selected for analysis soil and arsenic concentration of soil. In Keshabpur upazila, pazia mouza's selected tube well arsenic and iron concentration in soil is 67.95 ppb and 18.38 ppb. Again iron concentration is 350 ppm and 0.2 ppm. in Gurighona Mouza arsenic concentration of soil and water are 33.33 ppb and 0.07 ppb, iron concentration of soil and water are 180 ppm and 5.5 ppm. In Shofalakhathi arsenic concentration of soil and water are 55.97 ppb and 0.09 ppb, iron concentration of soil and water are 450 ppm and 3.2 ppm. In Biddankathi arsenic concentration of soil and water are 92.73 ppb and 1.03, ppb iron concentration of soil and water are 260 ppm and 8 ppm. In Pratap-pur arsenic concentration of soil and water are 72.16 ppb and 68.21 ppb, iron concentration of soil and water are 470 ppm and 3.8 ppm. From the above results it is revealed that there is no correlation between presence of arsenic and iron in soil and water respectively.

Table 4.4: Arsenic and iron concentration in soil and water of Keshabpur Upazila

Sample ID	District	Upazilla	Union	Mouza	Soil			Water			
					As(mg/kg)	As (ppb)	Fe(ppm)	Fe(gm/kg)	As(ppm)	As(ppb)	Fe(ppm)
1	Jessore	Keshobpur	Pazia	Pazia	6.795	67.95	350	35	0.02	18.38	0.2
2	Jessore	Keshobpur	Gurighona	Gurighona	3.333	33.33	180	18	0.07	72.73	5.5
3	Jessore	Keshobpur	Shofalakhathi	Shofalakhathi	5.597	55.97	450	45	0.09	85.89	3.2
4	Jessore	Keshobpur	Biddankathi	Biddankathi	9.273	92.73	260	26	0.13	112.7	8.0
5	Jessore	Keshobpur	Biddankathi	Biddankathi	5.539	55.39	200	20	0.25	24.81	3.0
6	Jessore	Keshobpur	Mazidpur	Pratap-pur	7.216	72.16	470	47	0.06	68.21	3.8
7	Jessore	Sharsha	Bagasra	Shamta	12.710	127.1	260	26	0.2	176	6.2

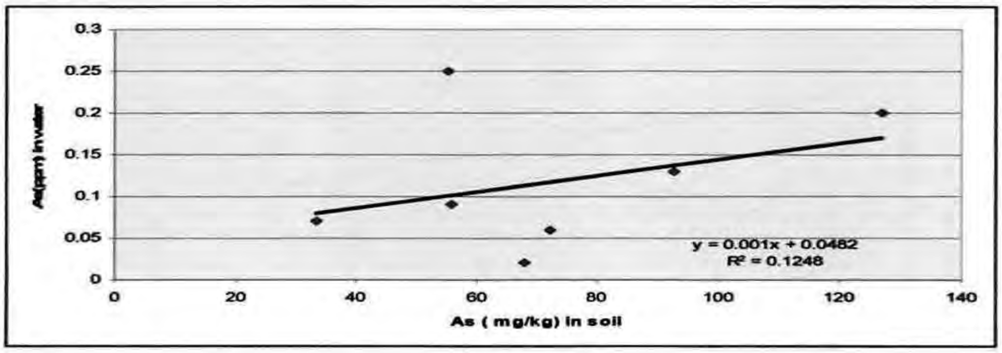


Figure 4.20: Relation between arsenic in groundwater and arsenic in irrigated soil in Keshabpur upazila

The Figure 4.20 shows the relation between arsenic in ground water and arsenic irrigated soil in Keshabpur upazila. From Figure it is found that there is no significant correlation between arsenic in ground water and arsenic irrigated soil.

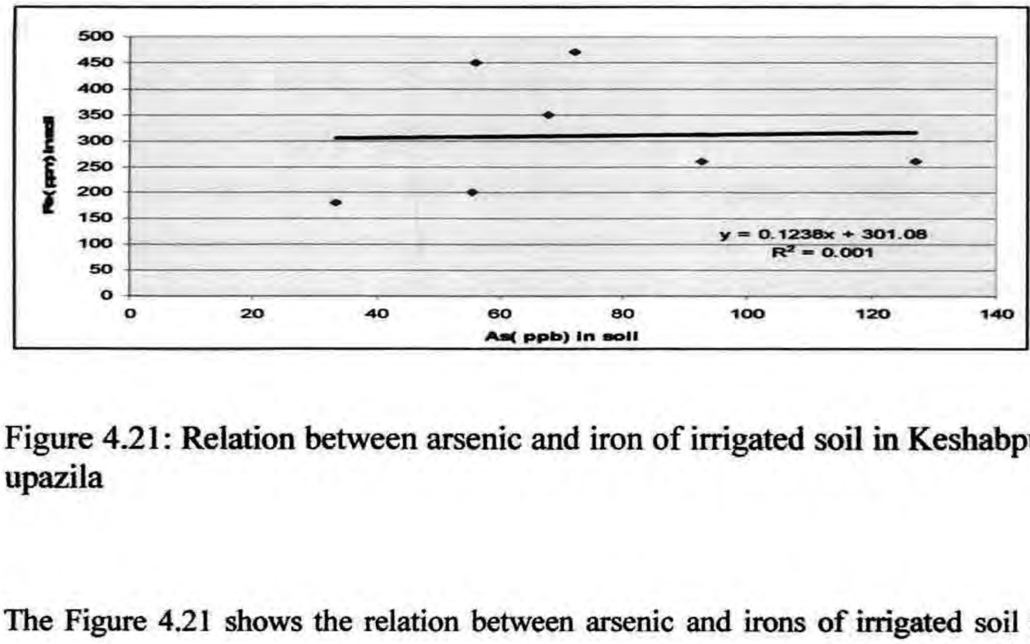


Figure 4.21: Relation between arsenic and iron of irrigated soil in Keshabpur upazila

The Figure 4.21 shows the relation between arsenic and irons of irrigated soil in Keshabpur upazila. From Figure it is found that there is no significant correlation between arsenic in ground water and arsenic irrigated soil.

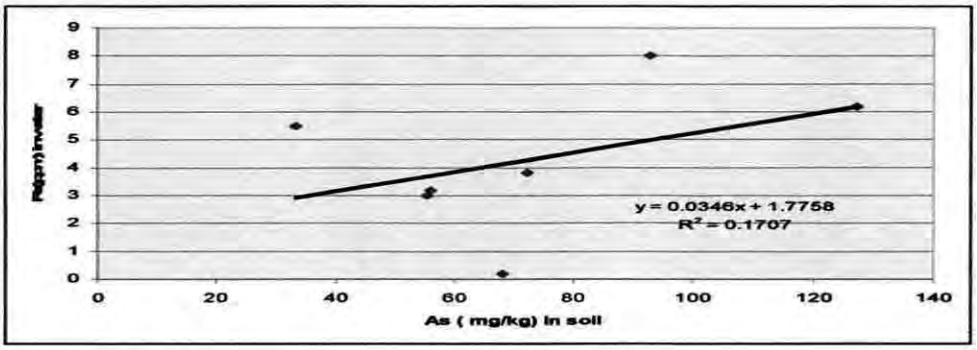


Figure 4.22: Relation between iron in groundwater and arsenic in irrigated soil in Keshabpur upazila

The Figure 4.22 shows the relation between iron in ground water and arsenic in irrigated soil in Keshabpur upazila. From Figure it is found that there are no significant correlations between arsenic in ground water and arsenic irrigated soil.

From Figure 4.20, Figure 4.21 and Figure 4.22 it is observe that arsenic of agricultural land is slightly related on arsenic of ground water but it depends on land and time. Analysis of the data and from the above graph it is shown that the values of the arsenic and iron of soil and water are different and there are no regular relationship between arsenic and iron both soil and water in Keshabpur Upazila but it is noted that arsenic adsorption to paddy field soil is a strong function of oxalate-extractable iron content of soil. Iron constant of paddy field soil, in turn, has been found to be related to the iron content in irrigation water. Thus, arsenic adsorption to paddy field soil depends, not only on the characteristics of soil, but also on the quality of irrigation water (Shaha, G.C., 2006).

Table 4.5 Nutrient concentration of soil (i.e Arsenic, iron, Magnesium and Zinc) of Keshabpur Upazila (mg/kg)

Sl No.	Thana name	Union	Mouza	As	Mg	Fe	Mn	Zn
1	Keshobpure	Panjia	Panjia	6.80	3.52	35.00	32.00	1.90
2	Keshobpure	Sufalakati	Sufalakati	5.60	2.46	45.00	2.00	0.80
3	Keshobpure	Gaurighona	Gaurighona	3.33	1.36	18.00	9.00	1.40
4	Keshobpure	Majidpur	Protappur	7.22	4.37	45.00	12.00	1.40
5	Keshobpure	Bidyanandakati	Bidyanandakati	9.27	2.11	26.00	13.00	1.90
6	Keshobpure	Bidyanandakati	Bidyanandakati	5.54	2.64	20.00	26.00	1.80

GIS based map of arsenic and iron concentration of soil in Keshabpur upazila

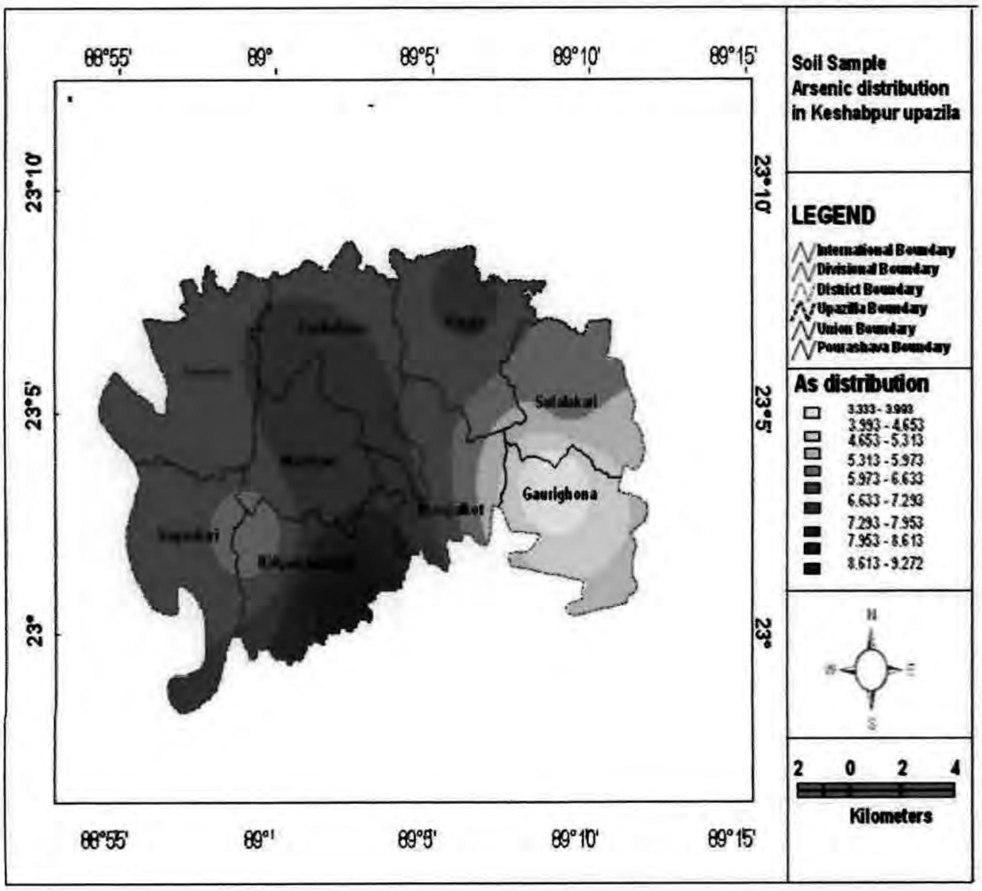


Figure 4.23 Arsenic concentration distribution of soil in Keshabpur upazila

The Figure 4.23 shows the different formation of red color. Deep red color indicates the highest arsenic concentration of Keshabpur upazila which is found in Bidyanandakati union (7.293 to 9.27 mg/kg). Slightly deep red color indicates the arsenic concentration range of 3.33 gm/kg to 2.37 gm/kg.

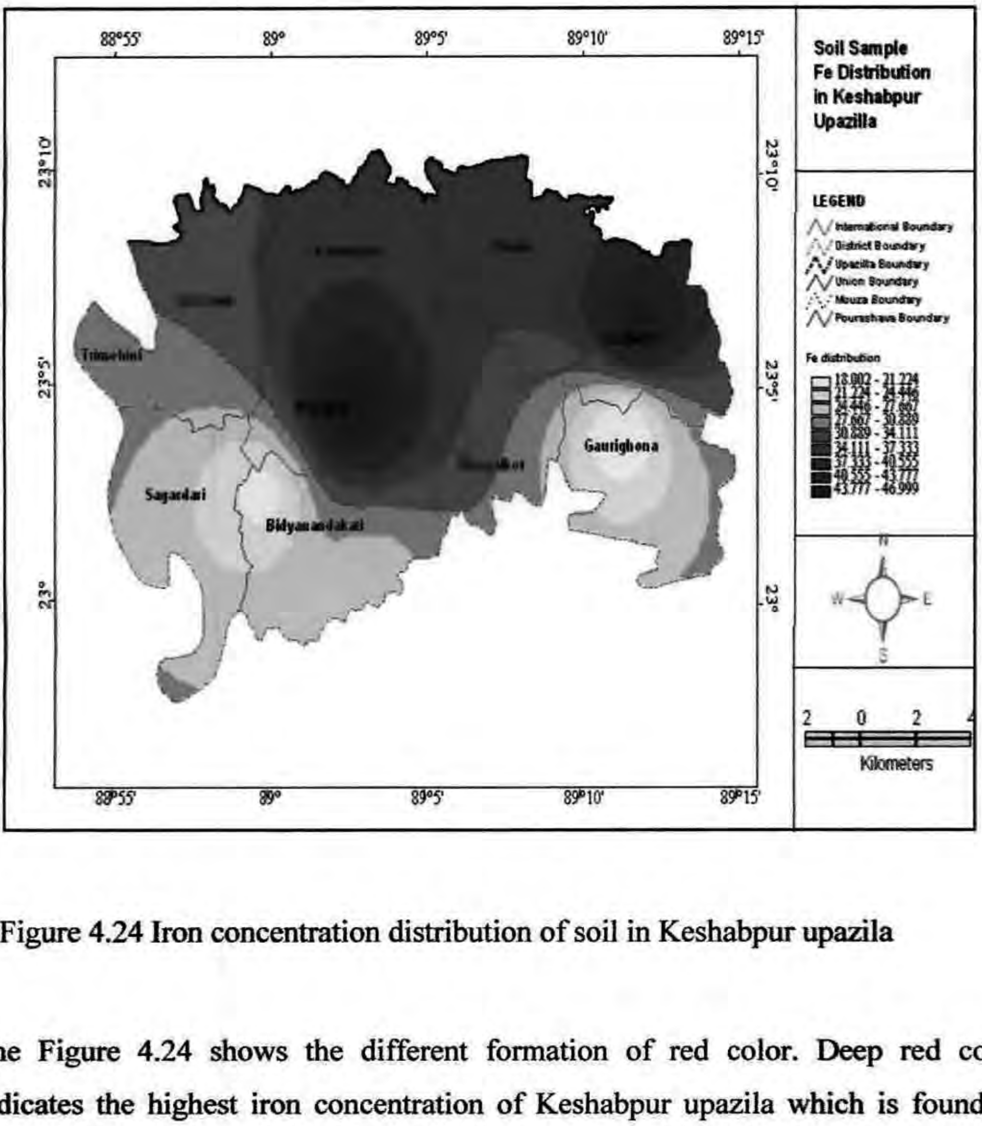


Figure 4.24 Iron concentration distribution of soil in Keshabpur upazila

The Figure 4.24 shows the different formation of red color. Deep red color indicates the highest iron concentration of Keshabpur upazila which is found in Majidpur and Sufalakhati union (43.33 to 48.999 gm/kg). Slightly deep red color indicates the arsenic concentration range of 30.00 gm/kg to 43.33 gm/kg.

From Figure 4.23 and 4.24 it is find that arsenic and iron of agricultural land are not directly correlated between one another. Analysis of the data and from the above graph it is shown that the values of the arsenic and iron of soil are different and there are no regular relationship between arsenic and iron of soil in Keshabpur Upazila. It may be noted that comparatively large amount of arsenic was found to be associated with amorphous iron hydroxides and there are a various in chemical forms of arsenic associated with sediment, depending on the geological history of the sediment (Chowdhuruy, M.A.K., 2006)

4.5 Arsenic concentration in Rice and Wheat

Wheat (Rabi season)

During Rabi season two field experiments were carried out one for wheat and other for rice. Arsenic concentrations of grain, straw and root of wheat crop showed variations in arsenic concentrations due to varietals differences and resulted significant difference at different levels under the farmers' practice condition. The values of arsenic contents of wheat grain, straw and root varied between 5.0 and 20.2 ppb, 22.1 and 46.4 ppb and 4.5 and 124.2 ppb, respectively. Only two irrigations were given during the growing season of wheat with arsenic laden irrigation water which added less arsenic to the soil. Arsenic concentrations generally show the following trend: grain<straw<root. With the exception of Gowrav and Protiva wheat varieties this general trend was found in wheat experiment. The values of root arsenic concentration of Protiva variety was even lower than grain arsenic concentration. In case of Gowrav variety the concentration of arsenic in root was lower than the straw arsenic concentrations, however, were below danger levels. It may be noted that the possible advarse effects of arsenic contaminated irrigation water on nutrient content i.e.protein and amylose (Alam, M. Z.2006).

Table 4.6 Arsenic concentration (ppb*) in wheat

Variety	Grain	Straw	Root
Shatabdi	16.00	46.4	70.3
Gowrav	6.6	46.2	33.7
Protiva	8.4	32.5	4.5
Sowrav	5.0	22.1	90.0
Kanchan	20.2	24.5	124.2

* 1000 ppb=1ppm or 1 mg/kg)

Yield of wheat varieties are obviously affected by the characteristics of wheat varieties as the experiment was carried out following the fertilizer recommendation guide (BRAC, 1997), the results showed that the fertilizer recommendation was not adequate to grow wheat crops. Grain yield of wheat ranged between 0.679 and 1.948 t/ha and straw varied from 2.43 to 2.97 t/ha. Highest grain yield was obtained with Gowrab and the lowest yield was obtained with Protiva. In case of straw yield Shatabdi varieties yield the highest value and the lowest value was found with Gowrab.

Rice (Rabi season).

Ten rice verities, included in the present experiment showed considerable variation among the studied parameters. Statistical analysis revealed different levels of significance (Table 4.8). The values of nitrogen, phosphorus, potassium and sulfur were in general in the ranges of concentration of respective elements was found at the maturity stage of rice crop

Arsenic concentrations of rice grain, straw and root are presented in Table 4.9. The *arsenic* concentrations of different segments of rice plants showed statistically highly significant variation. The values obtained with grain, straw and root agreed well with the general trend of variation, i.e., grain<straw< root. The arsenic concentrations of rice grain ranged from 9.50(BR-28 variety) to 61.00 (Minikat variety) ppb not harmful for human consumption. Straw arsenic varied between 53(BR-29) to 305 (BR-26) ppb and root arsenic concentrations varied between 1150(BR-3) and 1707 (BR-28) ppb. Some recent studies (Dittmar et al., 2006; Roberts et al., 2006) suggest that input of arsenic into pady field soils decreases significantly with increasing distance from the irrigation water inlet. Shaha, G.C., 2006 found that arsenic concentration in paddy grains from the unaffected areas vary from 0.33 to 0.44 mg/kg and those affected areas vary from 0.43 to 0.60 mg/kg and also found that higher arsenic concentration in irrigation water and top soil is clearly causing an increase of arsenic content in root, leaf and stem of paddy plants.

Table 4.7: Arsenic Concentration (ppb) in rice (Rabi season)

Variety	Grain	Straw	Root
Kajallata	11.20	291	1248
BR-3	7.10	193	1150
BR-16	13.80	207	1619
Jamaibabu	12.80	232	1933
Ratna	13.80	281	1643
BR-28	9.50	240	1707
BR-26	18.10	305	1611
BR-29	16.5	53	1567
Minikat	61.00	300	1601
BR-14	21.00	75	1576

Rice crop in Kharif season of 2007

In Kharif season, due to some unavoidable circumstances, experiment was not carried out following statistical design. However, four wide used rice varieties were grown. Yield parameters were not also recorded. Only grain and straw nutrients are presented in Table 4.11.

Table 4.8 Nutrient concentrations (%) of rice straw and grain

Variety	Grain				Straw			
	N	P	K	S	N	P	K	S
Sharnalata	1.18	0.055	2.45	0.274	1.51	0.169	0.202	0.094
BR-10	0.85	0.020	1.78	0.190	1.64	0.132	0.170	0.108
BR-30	1.31	0.035	1.55	0.167	1.75	0.148	0.196	0.096
BR-11	1.26	0.072	2.02	0.169	1.49	0.191	0.203	0.118

The observed data indicated that nitrogen concentration straw varied between 0.85 and 1.31% among the investigated varieties. The concentrations of phosphorus, potassium and Sulphur ranged from 0.020 to 0.072%, 1.55 to 2.45% and 0.167 to 0.274%, respectively. Data of grain analysis are presented in Table 4.11. The values of N, P, K and S varied from 1.49 to 1.75%, 0.132 to 0.191%, 0.170 to 0.203% and 0.094 to 0.118% respectively. The values are within the optimum range for all the rice. Arsenic concentration of straw were 65.1 ppb in Sharnalata, 226.4 ppb in BR-10, 265.97 ppb in BR-30 and 318.64 in BR-11 variety (Table 4.11). In terms of concentration, the highest value was found in BR-11 variety. Compare to the values obtained with straw, grain contains far lower values of arsenic. Rice varieties Sharnalata, BR-10, BR-30 and BR-11 contained 0.95, 1.49, 1.98 and 9.95 ppb, respectively. Like the concentration of straw, BR-11 yield the highest value of grain arsenic content, which indicated that BR-11 accumulate more arsenic than other rice varieties.

Table 4.9 Arsenic Concentration (ppb) in Rice (Kharip Season)

Variety	Grain	Straw	Root
Sharnalata	0.95	65.11	1686
BR-10	1.49	226.47	1815
BR-30	1.98	265.97	1041
BR-11	9.95	318.64	1807

An examination of the data presented in Table 4.9, Table 4.10 and Table 4.11 clearly indicated that in Rabi season greater uptake of arsenic occurred by rice varieties compared to wheat varieties. This result indicated that rice accumulated more arsenic which might be due to more addition of water soluble arsenic through irrigation water. Arsenic transfer factor calculated for grain to straw, grain to root and straw to reveal that a large amount of arsenic remained in the soil as root arsenic after crop harvest. Mineralization of the roots can release arsenic to the soil medium which may become available to next crop or may be adsorbed by soil constituents. This indicates the necessary to investigate the fate of arsenic in the soil environment.

Table 4.10: Ratio of Grain and Straw, Grain and Root, Straw and Root of Rice

Variety	Grain: Straw	Grain: Root, Grain	Straw : Root
Kajallata	0.038	0.009	0.233
BR-3	0.037	0.006	0.168
BR-16	0.067	0.009	0.128
Jamaibabu	0.055	0.008	0.142
ratna	0.049	0.008	0.171
BR-28	0.040	0.006	0.141
BR-26	0.059	0.011	0.189
BR-29	0.311	0.011	0.034
Minikat	0.203	0.038	0.187
BR-14	0.280	0.013	0.048

Table 4.11: Ratio of Grain and Straw, Grain and Root, Straw and Root in Wheat (Rabi Season)

Variety	Grain: Straw	Grain: Root	Straw : Root
Shatabdi	0.345	0.228	0.660
Gowrav	0.143	0.196	1.371
Protiva	0.258	1.867	7.222
Sowrav	0.226	0.056	0.246
Kanchan	0.824	0.163	0.197

This can be explained by the fact that rice crop is grown under rain fed condition during Kharif season and there is little chance to add arsenic to the soil but it depend to land. The residual concentration of arsenic present in soil was probably contributed to the uptake of arsenic by rice plants in Kharif season.

Table 4.12: Ratio of Grain and Satraw, Grain and Root, Straw and Root in Wheat (Kharif)

Variety	Grain: Straw	Grain: Root	Straw : Root
Sharnalata	0.0146	0.0006	0.0386
BR-10	0.0065	0.0008	0.1248
BR-30	0.0074	0.0019	0.2255
BR-11	0.0312	0.0055	0.1763

From above discussion it is showed that arsenic concentration in Rice is higher than Wheat, Because Rice needs more Irrigation than wheat at a season.

<u>**Note:**</u> Arsenic concentrations in paddy and wheat plant are less/differ from other studies due to plot condition and time of collection sample. So further studies must be required to know the accurate condition between arsenic concentration in plant and soil.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

On the basis of the analysis and discussion in the previous chapters, the following conclusions can be drawn:

- Arsenic content of Irrigation water is found randomly that is vary from place to place. There is no significant correlation between arsenic and other water parameters i.e. iron, sulphate and phosphate.
- Relationship between arsenic concentration in irrigation water and arsenic concentration in irrigated land is insignificant.
- Different wheat and rice varieties grown in arsenic affected areas at field condition and uptake of arsenic by different wheat and rice varieties are different. The values of arsenic concentration obtained in grain, straw and root agreed well with the general trend of variation, i.e., grain<straw< root.
- Yield of rice and wheat is not dependent on arsenic concentration of irrigated land and water.
- In case of wheat and rice, for production of wheat is safer than rice. Arsenic intake by wheat is lower than rice in arsenic contaminated irrigated water.

5.2 Recommendations

For safe and judicious use of Irrigation water and irrigated area the following recommendations are made to extend the present study and future work:

- In a regular basis water and soil should be examined and needed to find appropriate cause of entering arsenic in soil and water.
- Transformation of arsenic in soil under varied conditions. This objective includes adsorption, fixation and fractionation of arsenic in soils and retention by

the soils of different arsenic contaminated areas of Bangladesh because Adsorption-desorption depend on a wide range of factors, including soil characteristics (e.g: sand, silt and clay contents).

- BADC should be encouraged to find out the accurate GPS coordinates of its monitoring wells using appropriate GPS device, so that a more accurate database could be developed. Water quality and soil nutrient should be tested at the same location at least three years at different season for accurate understanding of entering arsenic in water and soil.

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