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Groundwater Arsenic Contamination and its Distribution in Bhojpur District, Bihar, India

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ABSTRACT

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Arsenic, Iron, Drinking water and contaminations

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Ground water is the major source of drinking water in both rural and urban areas which may be contaminated by various means, Arsenic is one of them. Forty five hand-pump and river samples (containing 250ml each) from different blocks of Bhojpur district, Bihar were collected in sterile containers and analyzed. The values were found as pH (6.5-8.5), EC (277-1415µS/cm), TDS (237-1034 mg/L), As (0-785 ppb), Al (35.1-117 ppb),Cd (0-83 ppb), Cr (0-5 ppb),Cu (0-10 ppb), Ni (0-11 ppb), Pb (0-24 ppb), Mn (2.1-1303 ppb), Zn (110-2190 ppb) and Fe (0.06-14.39 mg/L). The results compared with the drinking water standard prescribed by Bureau of Indian Standard (BIS) and it was observed that all the water quality parameters were within permissible limit of drinking water except As and Fe for most of the samples. Almost 40% of samples were within the acceptable limit of As (10 ppb) prescribed by BIS, 2012. Approximately ~60% of water samples were enriched with As concentrations >10 µg/L, which ranged from below detectable limit (BDL) to 785 µg/L (average 162 µg/L). In case of Fe as 68.88% which exceeded the acceptable limit of 0.30 ppm as prescribed by BIS, 2012. High concentration of iron and arsenic may be attributed to the dissolution of pyrite bearing minerals from the geological strata.

Introduction

Groundwater contains wide variety of dissolved inorganic chemical constituents in various concentrations, resulting from chemical and biochemical interactions between water and the geologic materials. Some regions of various states of India are contaminated by Salinity, Arsenic, Fluoride, Iron and Nitrate etc. Higher concentration of arsenic in ground water is generally reported to be geogenic. Arsenic in ground water beyond the BIS acceptable and permissible limit of 10 and 50 ppb respectively has been reported from many states namely West Bengal, Bihar, Uttar Pradesh, Assam, Manipur, Jharkhand, Punjab, Haryana, Chhattisgarh and Karnataka etc (CGWB, 2015). Mostly the Indo Ganetic alluvium and the Brahmaputra alluvium have higher concentration of arsenic in localized pockets. Fluoride contamination (more than 1.5 mg/l) in ground water is widely prevalent in different parts of India, mostly in the states of Telangana, Andhra Pradesh, Rajasthan, Maharashtra, Madhya Pradesh, West Bengal, Bihar, Odisha, Punjab, Haryana, Tamil Nadu, Uttar Pradesh, Karnataka and Gujarat (CGWB, 2015). Some parts of Chhattisgarh, Delhi and Kerala are also affected by Fluoride contamination. Salinity in ground water is found mainly in western, north western and southern parts of India. Salinity has been observed in all major aquifer systems. Inland salinity caused by high sulphate in ground water has also been reported from some parts of the country. High levels of iron in ground water (more than 0.3 mg/l) have been reported from many states (CGWB 2015). Pollution due to human and animal wastes and fertilizer application has resulted in higher levels of potassium and nitrate in ground water in some parts of the country. Ground water pollution due to indiscriminate disposal of industrial effluents has been reported as localised contamination in major industrial zones.

Arsenic in Groundwater

Arsenic is a metalloid with symbol As an atomic number 33, atomic mass 74.92. Arsenic forms colorless, odorless, crystalline compounds As_2O_3 and As_2O_5, which are hygroscopic in nature and readily soluble in water to form acidic solutions. Arsenic is found in the natural environment in abundance in the Earth's crust and in small quantities in rock, soil, water and air. The most common oxidation states for arsenic are: -3 (arsenides: usually alloy-like intermetallic compounds), +3 (arsenites (As (III) and most organoarsenic compounds), and +5 (arsenates (As (V)): the most stable inorganic arsenic oxy-compounds. It can exist in organic and inorganic form. Inorganic arsenic is generally more toxic than organic arsenic. Inorganic arsenic occurs naturally in many types of rocks and it is generally found with sulphide ore arsenopyrite. Inorganic arsenic compounds known to be human carcinogens. Arsenic in elemental form is insoluble in water but it is soluble in oxidised form.Arsenic is a natural constituent in bedrock and soil. It usually occurs at low concentrations (average 1-2 mg/kg) in the Earth's crust (Behattacharya *et al.,* 2002), but may be concentrated in certain rock types and especially in gold and sulphide-bearing ore deposits and occurrences. Pyrite [FeS_2; or arsenian pyrite $Fe(AsS)_2$] and arsenopyrite [FeAsS] are typical sulphide minerals containing As. Arsenic is mobilized through a combination of natural processes such as weathering reactions, biological activity, and volcanic emissions as well as through a range of anthropogenic activities such as gold mining, nonferrous smelting, petroleum-refining, combustion of fossil fuel in power plants, and the use of arsenical pesticides and herbicides (Biswas *et al.*, 2008; Smedley and Kinniburgh, 2002; Violante *et al.,* 2006). Arsenic is immediately dangerous to life or health at 5.0 mg/m^3. The human body does not readily absorb the element itself; hence, pure arsenic is much less dangerous than arsenite (As^{+3}) compounds such as arsenic trihydride or arsine (AsH_3) and arsenic trioxide (As_2O_3), which are absorbed easily and are carcinogenic at high toxicity. Humans are exposed to arsenic, mainly inorganic arsenic and predominantly through contaminated drinking water, whereas inhalation and skin absorption are minor routes of exposure (Shi *et al.,* 2004). Chronic arsenicism has affected more than 300 million people worldwide, approximately 85 million of whom reside in Bangladesh. The major arsenic-prone areas have been reported in large deltas and/or along major river basins across the world (Fendorf *et al.,* 2010; Shankar *et al.,* 2014). A number of such arsenic prone regions in the world with deltas and river basins include alluvial and deltaic aquifers in Bangladesh (Chakraborti *et al.*, 2015; Smith *et al.*, 2000a), the Paraiba do Sul delta in Brazil (Mirlean *et al.*, 2014), the Ganges-Brahmaputra Plain in India (Das *et al.*, 2009), the Red river basin and Mekong Delta in Vietnam (Nguyen *et al.*, 2009) etc. The clinical symptoms of arsenic toxicity in human body include skin itching to sun rays, burning and watering of the eyes, weight loss, loss of appetite, weakness, fatigue, limited physical activities and working capacities, chronic respiratory problems, moderate to severe anaemia etc.

Heavy withdrawal of groundwater for fulfilling the needs of the increasing population in Bengal Basin resulted in increased arsenic level in the groundwater. Mobilization of arsenic in Bengal delta is further interfered by microbial activities and interactions. Arsenic naturally occurs in over 200 different mineral forms, of which around 60% are arsenates, 20% are sulfides and sulfosalts and the rest 20% are arsenides, arsenites, oxides, silicates and elemental arsenic (Bissen and Frimmel, 2003).

Major arsenic containing primary minerals are arsenopyrite (FeAsS), realgar (As_4S_4), and orpiment (As_2S_3). Realgar (As_4S_4) and orpiment (As_2S_3) are the two common reduced forms of arsenic whereas the oxidized form is the mineral arsenolite (As_2O_3).

Exposure to sufficiently high concentrations of inorganic arsenic in natural environment has proved to be harmful to the organisms.

The main pathways of arsenic exposure to the human beings include ingestion of drinking water and consumption of foods and, to a lesser extent, inhalation of air.

Materials and Methods

Study area

Bhojpur district is situated in Bihar state and it is one of the thirty-eight districts of Bihar state and its administrative headquarter is located in Ara town. The total geographical area of Bhojpur district is 2395 km2. Bhojpur district falls within 25º 10'' to 25º 40'' N and 83º45'' to 84º 45'' E. The district area is bounded by the river Ganga in the north, Vindhyan hills in the south, the river Son in the east and Dharmawati-Gangi Rivers in the west. The urban and rural populations of the district are 2331450 and 388705 respectively, with total population around 2720155 (Census 2011). The district has three Sub Divisions namely Ara Sadar, Jagdishpur and Piro. The blocks of the district include Ara Sadar, Udwantnagar, Jagdishpur, Koilwar, Sahar, Barhara, Sandesh, Shahpur, Charpokhari, Piro, Tarari, Bihia, Agiawon and Garhani as shown in Figure 1.

Climate and rainfall

The study area has warm and humid climate.. The average temperature reaches 39^0 C during the months of April and May, whereas temperature decreases upto 6.3^0 C in the month of January. In the study area monsoon starts mostly from the mid of June and continues up to the end of the September. The normal annual rainfall of the district is 1080 mm which is calculated based on seventy years (1901- 1970) annual rainfall data (CGWB, 2013). The annual rainfall of the district varies from 1025 mm to 1106 mm. About 85.46 % of the total annual rainfall is obtained during monsoon period and the rest (only 14.54 % approximately) occurs during the months of November to May (non monsoon season).

To measure the concentration of various water quality constituents of surface water or groundwater, specialized sampling and sample handling procedures are required. Total 45 water samples were collected from hand pumps and rivers during May, 2019 in, clean polypropylene bottles for trace metals analyses. The first few strokes of hand pump water were discarded to minimize the impact of stored waters. For analysis of trace metals, samples were acidified with conc. HNO_3 at the rate of 2 ml/L of water samples.

The physical parameters such as pH, electrical conductivity etc. was determined in the field using portable instruments (Hach, HQ30d portable meter). The water samples were brought to Roorkee and analyzed for various parameters in the laboratory of water quality lab, National Institute of Hydrology, Roorkee. The physico -chemical parameters were analyzed as per standard method (APHA, 2012;Jain and Bhatia, 1988).

The parameters analyzed to assess the water quality are pH, Electrical conductivity (E.C), Turbidity, Total Dissolve Solids (TDS), Arsenic, Iron, Chromium, Nickel, Copper, Zinc, aluminum, Cadmium, Lead and Manganese.

The pH and electrical conductivity was measured by electrometric method and Arsenic and all other trace metals were analyzed by the instrument ICP OES.

Trace metals

Trace metals are elements such as Co, As, Cr, Fe, Cu, Mn, Zn and Se that generally occur at very low quantity in the environment. Living things need very small amounts of some trace metals, but high levels of these same metals can be toxic. For example, for many living things iron is an essential element, iron transports oxygen around the body in human blood.

Principle of ICP OES

The trace element analysis was conducted by ICP-OES (Inductively Coupled Plasma optical emission spectrometry). When plasma energy is given to an analysis sample from outside, the component elements (atoms) is excited. When the excited atoms return to low energy position, emission rays (spectrum rays) are released and the emission rays that correspond to the photon wavelength are measured. The element type is determined based on the position of the photon rays, and the content of each element is determined based on the rays' intensity.

To generate plasma, first, argon gas is supplied to torch coil, and high frequency electric current is applied to the work coil at the tip of the torch tube. Using the electromagnetic field created in the torch tube by the high frequency current, argon gas is ionized and plasma is generated. This plasma has high electron density and temperature (10000K) and this energy is used in the excitation-emission of the sample. Solution samples are introduced into the plasma in an atomized state through the narrow tube in the center of the torch tube.

Results and Discussion

Total forty-five groundwater and river water samples were collected from the Bhojpur District, Bihar. The samples were analysed for trace metals for which analytical results of the chemical analysis are given in Table 1.

pH is one of the most important parameter in water chemistry and is defined as $\log[H^+]$, and is measured as intensity of acidity or alkalinity on a scale ranging from 0-14. In natural water, pH is governed by the equilibrium between carbon dioxide, bicarbonate and carbonates ions and in general, ranges between pH 4.5 to 8.5. Although pH has no direct impact on the health of consumers, it is one of the most important operational water quality parameter. BIS (2012) has prescribed pH value in the range of 6.5 to 8.5 for for drinking water purpose. The pH of the water samples of study area varied from 6.9 to 8.5 with an average value of 7.57 (Table 1) and were well within the drinking water standards as prescribed by BIS (2012).

Electrical conductivity (EC) is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions; on their total concentration, mobility, and valence; and on the temperature of measurement. The electrical conductivity and dissolved salt concentrations are directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and/or other mineral contamination. In study area the electrical conductivity (EC) values varied from 277 to 1415 μScm^{-1} with an average value of 683 μScm^{-1} (Table 1) in groundwater.

Total Dissolved Solid (TDS) in water includes all dissolved material in solution, whether ionized or not. TDS is numerical sum of all mineral constituents dissolved in water and is expressed in mg/l.

TDS in drinking-water originates from natural sources, sewage, urban runoff and industrial wastewater. Concentrations of TDS in water vary considerably in different geological regions owing to differences in the solubility of minerals. BIS (2012) have prescribed 500 mg/l as the acceptable limit and 2000 mg/l as permissible limit in absence of alternate source for drinking and other domestic usage. The total dissolved solids concentration in the all the analyzed water sample of the study area ranged from 177 to 905 mg/l with an average value of 437 mg/l given in (Table 1). The results show that in 48 % of the sample TDS exceeded acceptable limit (500 mg/l) and none of the sample it exceeded the permissible limit of BIS (2012).

Arsenic and other heavy metals distribution

Heavy metals in ground water have a considerable significance due to their toxicity and adsorption behavior. Despite the presence of trace concentrations of Cr, Mn, Co, Cu and Zn in the aquatic environment, which is essential to a number of life processes, high concentrations of these metals become toxic. The major sources of heavy metals in ground and surface water include weathering of rock minerals, discharge of sewage and other waste effluents on land and runoff water. The results of trace metal of the study area are given in the Table 1. The toxic effects of these elements and extent of their contamination in ground water is discussed in the following sections

Arsenic (As)

The results suggest that almost 40% of analysed samples fall within the acceptable limit of As (10 ppb) prescribed by BIS, 2012 (Fig. 2 and Fig. 3).

Approximately ~60% of water samples collected from the study area were enriched with dissolved As concentrations >10 µg/L, and it ranged from below detectable limit (BDL) to 785 µg/L (average 162 µg/L). Among the analysed samples about 11% samples showed marginally elevated As (ranging between 10-50 µg/L) concentration in the Bhojpur area, whereas about 27 and 22 % of the analysed samples were in the range of 50-100 µg/L and above 100 µg/L respectively in the study area. In the present study, all the collected ground water samples were of shallow depth (Private hand pump/Tube wells, India Mark Hand pump: 30 to 160 ft).

Total As concentrations was extensively present in the ground water of study area along River Ganga as it can be observed from spatial distribution map of Arsenic (Fig. 4), which shows the location of two hotspot in the Bhojpur area. These regions are located along the Ganga river flood plains.

Iron (Fe)

The concentration of iron in the ground water of the study area ranged from 0.06 to 14.39 ppm with average concentration 2.81ppm. The Bureau of Indian Standards has recommended 0.30 ppm as the acceptable limit.

It is observed that 68.88% of the samples of the area exceeded the acceptable limit of 0.30 ppm. High concentration of iron may be attributed to the dissolution of iron bearing minerals from the soil strata. High concentrations of iron generally cause bitter and astringent taste to water.

The objection to iron in the distribution system is not due to health reason but for staining of laundry and plumbing fixtures and appearance.

Manganese (Mn)

The concentration of manganese ranges from 2.1 to 1303 ppb. A concentration of 100 ppb has been recommended as a acceptable limit and 300 ppb as the permissible limit for drinking water (BIS, 2012).

It is revealed from the results that about 15.55% of the analysed samples of the study area fall within the acceptable limit of 100 ppb, and 35.35% samples exceeded the acceptable limit but were within the permissible limit of 300 ppb whereas 64.65% of sample exceeded the permissible limit too.

Aluminum (Al)

The concentration of Aluminum in the ground water of the study area ranged from 35.1 to 1171 ppb with an average of 124 ppb. The Bureau of Indian Standards has recommended 30 ppb as the acceptable limit and 200 ppb as the permissible limit for drinking water (BIS, 2012).

It was evident from the results that 0.0% collected samples from the study area fell within the acceptable limit, 100 % exceeded the acceptable limit and only 13.33% exceeded the permissible limit for drinking purpose.

Copper (Cu)

The concentration of copper ranged from BDL to 10 ppb, with an average value 4 ppb. The Bureau of Indian Standards has recommended 50 ppb as the acceptable limit and 1500 ppb as the permissible limit in the absence of alternate source (BIS, 2012).

In the study area, 100% of the samples fell well within the acceptable limit of 0.5 mg/l and none of the sample exceeded the permissible limit for drinking water.

Lead (Pb)

In the study area, the concentration of lead ranged from BDL to 24 ppb. The Bureau of Indian Standards has prescribed 50 ppb lead as the acceptable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. In the study area, all samples fell well within the limit for drinking water.

Chromium (Cr)

The concentration of chromium was found below BDL to 5 ppb. A concentration of 50 ppb has been recommended as acceptable limit for drinking water (BIS, 2012).

In the study area, almost all the samples fell well within the acceptable limit for drinking water.

Table.1 Distribution of As and other heavy metals concentration in the study area

Sample Code	Location	pH	Ec	TDS	As ppb	Al ppb	Cd ppb	Cr ppb	Cu ppb	Ni ppb	Pb ppb	Mn ppb	Zn ppb	Fe ppm
1	Paiga	7	592	448	167	57	ND	ND	3	ND	ND	599	161	3.43
2	Paiga	6.9	956	565	160	228	ND	ND	10	ND	ND	452	381	3.17
3	Semaria Ojhapati	7	640	469	35	48	ND	ND	3	ND	12	322	150	1.3
4	Semaria Ojhapati	7.1	567	460	7	51	1	ND	5	ND	5	348	848	0.67
5	Semaria Ojhapati	7.1	636	475	105	46	1	ND	3	ND	ND	301	144	3.7
6	Semaria Ojhapati	7.2	691	572	752	53	1	ND	ND	ND	6	390	212	6.17
7	Semaria Ojhapati	7.2	598	529	10	50	ND	ND	4	ND	12	282	161	0.14
8	Semaria Ojhapati	7.1	979	773	777	76	1	ND	4	ND	ND	636	147	14.39
9	Semaria Ojhapati	7.6	498	469	8	53	1	ND	5	ND	ND	19	302	0.16
10	Semaria Ojhapati	7.3	622	460	3	49	ND	2	2	ND	4	334	170	0.18
11	Sahana (Mangla)	7.3	665	541	147	51	1	ND	3	ND	16	277	163	3.61
12	Sudarpur Barja	7.3	470	419	ND	51	ND	ND	3	ND	ND	511	168	0.34
13	Balaharpur	7.7	571	487	ND	36	ND	ND	4	ND	ND	357	182	0.3
14	Balaharpur	7.5	456	376	ND	35	ND	2	4	ND	ND	346	167	0.06
15	Barahara (Ganga)	8	540	456	74	332	ND	ND	3	ND	ND	158	202	0.58
16	Barahara	7.6	541	487	95	47	ND	ND	7	7	24	126	1687	0.19
17	Sirsiyan	7.2	772	606	785	57	1	ND	ND	2	10	745	245	13.6
18	Sirsiyan	7.5	680	566	165	58	ND	ND	3	ND	ND	207	214	3.55
19	Hazipur	7.8	383	342	30	302	ND	ND	7	11	8	909	288	4.31
20	Chamarpur	7.2	732	646	338	53	1	ND	4	ND	8	624	196	5.53
21	Chamarpur	7.9	801	680	104	54	ND	ND	3	ND	7	140	208	2.75

22	Sirhiya	7.4	692	490	ND	54	ND	ND	2	ND	ND	569	209	0.2
23	Sirhiya	7.5	724	600	40	83	1	2	6	ND	12	525	2190	1.72
24	Sirsiya	7.5	560	415	ND	60	3	ND	5	ND	6	490	143	0.2
25	Ishwarpura	7.5	1050	1034	360	60	1	ND	4	ND	ND	330	183	0.3
26	Ishwarpura	7.9	629	469	106	49	1	ND	0	ND	9	127	154	1.28
27	Ishwarpura	7.7	810	768	346	58	1	ND	4	ND	6	503	201	6.81
28	Ishwarpura	7.5	925	740	659	69	1	ND	3	ND	ND	587	167	8.25
29	Ishwarpura	7.1	1415	897	497	75	1	ND	2	ND	12	626	382	13.65
30	Ishwarpura	8.1	964	725	765	122	1	ND	2	ND	8	782	199	3.1
31	Baligaon	7.5	522	463	6	48	ND	ND	5	ND	12	470	151	0.11
32	Naika Tola	7.7	405	360	ND	37	1	ND	3	3	9	89	140	0.23
33	Jaithwar	7.5	850	594	ND	80	ND	5	3	ND	ND	4	138	0.12
34	Bahnuwa	7.4	629	497	ND	58	ND	2	2	ND	8	8	174	0.23
35	Anhari	8.3	277	237	ND	577	ND	ND	5	ND	ND	37	169	0.75
36	Anhari	8	482	379	ND	39	1	2	3	ND	13	4	116	0.15
37	Sahar	8.2	815	623	12	64	83	5	4	ND	ND	2	154	0.1
38	Bhagwanpur	8.1	942	403	5	47	ND	ND	2	4	15	306	128	0.12
39	Bibiganj	7.9	592	402	139	43	1	ND	ND	4	5	380	110	1.78
40	Maulighat	8.5	526	381	17	1171	1	1	6	ND	ND	132	141	1.76
41	Maulighat	7.6	1033	828	ND	70	1	ND	1	ND	ND	1303	163	0.11
42	Mauzampur	7.7	815	709	138	62	1	ND	6	ND	12	324	1631	4.36
43	Bindgaon	8.2	380	267	ND	732	ND	ND	6	2	ND	111	155	1.15
44	Bindgaon	7.7	732	593	252	59	1	ND	2	ND	ND	549	129	3.53
45	Manikpur	7.9	584	495	193	68	1	ND	3	ND	ND	1221	250	6.96
Minimum		6.9	277	237	**ND**	**35.1**	**ND**	**ND**	**ND**	**ND**	**ND**	**2.1**	**110**	**0.06**
Maximum		8.5	1415	1034	**785**	**83**	**5**	**10**	**11**	**24**	**1303**	**2190**	**14.39**	**14.39**
Average		7.6	683	538	**162**	**2**	**0**	**4**	**1**	**5**	**390**	**310**	**2.81**	**2.81**

Fig.1 Study Area of Bhojpur district

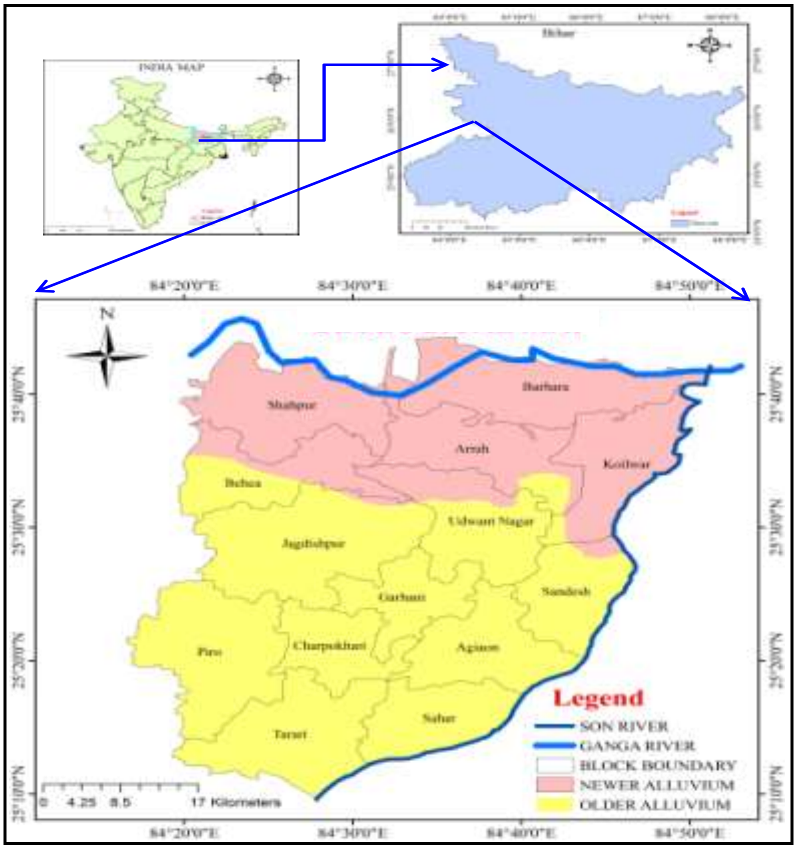


Fig.2 Sampling Location of Study Area

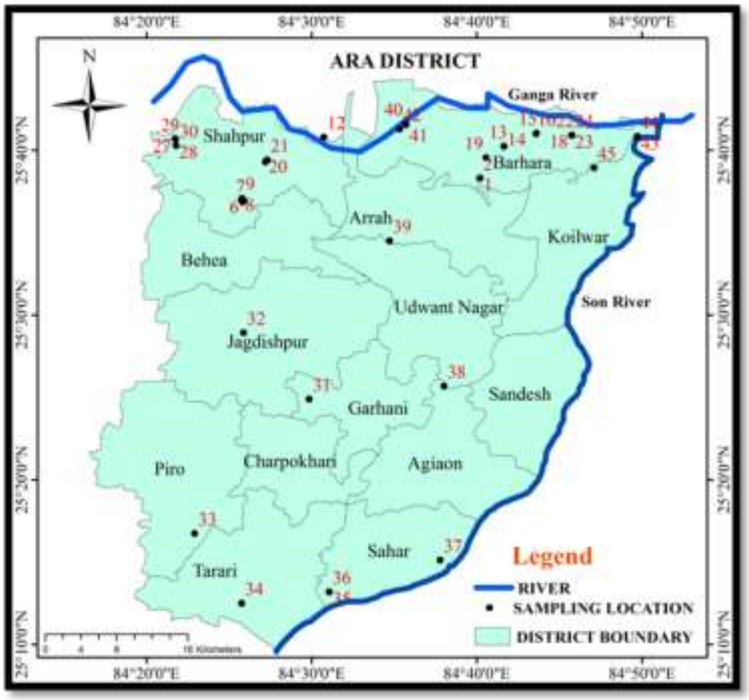


Fig.3 Arsenic affected sample in (%) of Bhojpur district

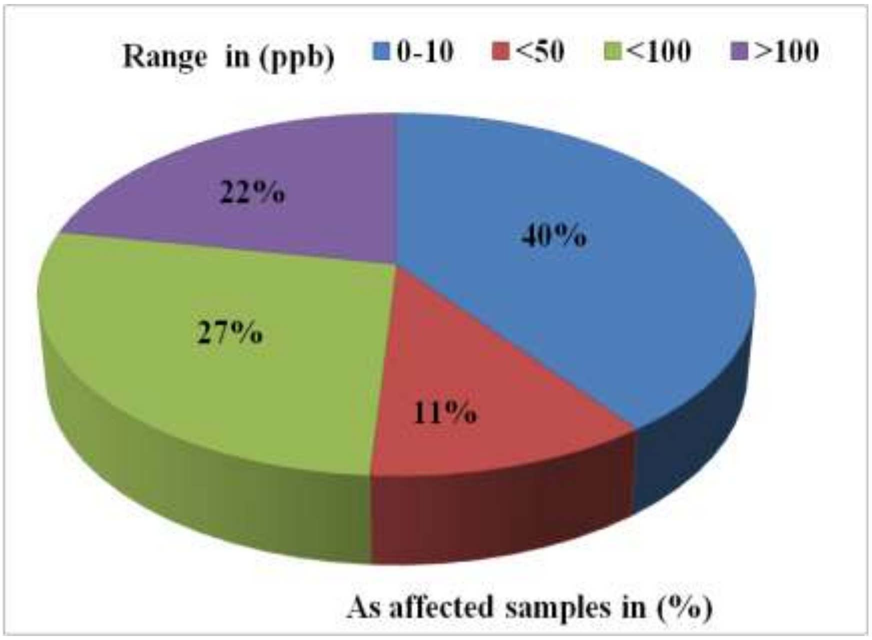
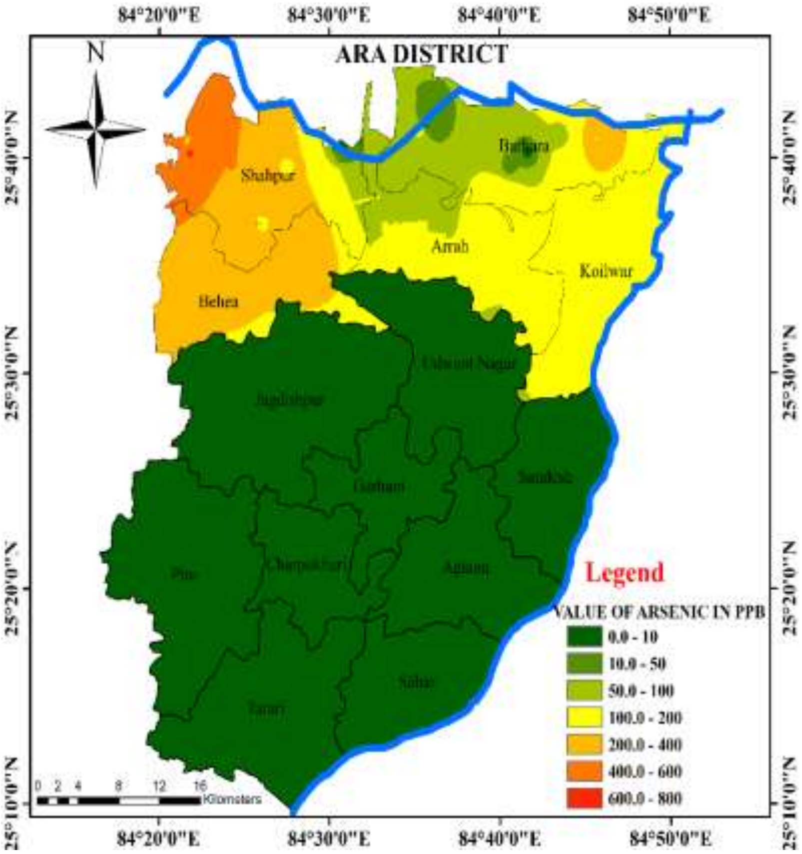


Fig.4 As distribution map of the study area



Cadmium (Cd)

Cadmium is a non essential non-beneficial element known to have a high toxic potential. The cadmium content in the study area varied from BDL to 83 ppb during the study period. The Bureau of Indian Standards has prescribed 3ppb cadmium as the acceptable limit for drinking water (BIS, 2012). Beyond this limit, the water becomes toxic. In the study area, only 4.44 % samples fell beyond the acceptable limit during this sampling period.

Nickel (Ni)

The concentration of Nickel in the ground water of the study area ranged from BDL to 11 ppb. The Bureau of Indian Standards has recommended 30 ppb as the permissible limit for drinking water (BIS, 2012). It was evident from the results that nickel concentration in all the groundwater samples fell well within the permissible limit.

Zinc (Zn)

The concentration of zinc in the study area ranged from 110 ppb to 2190 ppb. The Bureau of Indian Standards has prescribed 5000 ppb zinc as the acceptable limit and 15000 ppb as the permissible limit for drinking water (BIS, 2012). In the study area, 100 percent of total analysed samples were found under the acceptable limit.

The deterioration of ground water quality due to geogenic and anthropogenic activities causes the concern for policy makers. The quality of ground water has undergone a change to an extent that the use of such water could be hazardous. Ground water contamination with arsenic (As) is one of the major threats to human health. In India, high concentration of arsenic beyond permissible limit of 0.05 mg/l in ground water has been reported from 86 districts of 10 States. States like West Bengal, Bihar, Uttar Pradesh, Assam, Madhya Pradesh and parts of Chandigarh are facing acute problem of arsenic contamination. The ground water of Bhojpur district, Bihar has been reported to be severely contaminated with arsenic. In the present study, forty five water samples were collected from all the blocks, mainly focussing on four blocks namely Shahpur, Barhara, Ara and Koilwar of Bhojpur district, Bihar. The Arsenic and Iron has been found in the range (0-785 ppb) and (0.06-14.39 mg/L) respectively in the study area. The enrichment of As was encountered in the sampling sites that were close to the flood plain of Ganges river. For better drinking management policy, government and other water supply and investigation department may target continuous monitoring of the arsenic affected area and a detailed hydro-geochemical and arsenic genesis study should be carried out for better understanding of arsenic occurrence.

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