*International Research Journal of Environment Sciences*_____ ISSN 2319–1414
Vol. **4(5),** 47-56, May **(2015)** *Int. Res. J. Environment Sci.*

Arsenic Distribution in Groundwater and its Effect on Health of People of Kishanganj, Bihar, India

Kumar A[1*], Kumar V[2] and Kumar A[3]
[1]P.G. Department of Chemistry, D. S. College, Katihar, BNMU, Bihar-854105, INDIA
[2]Department of Chemistry, Kishanganj College of Engineering and Technology, Veriadangi, Kishanganj, BNMU, Bihar-855107, INDIA
[3]Department of Zoology, L.S.T.G. College, Aungaridham, Nalanda, M.U., Bihar, 801301, INDIA

Available online at: www.isca.in, www.isca.me
Received 1st March 2015, revised 25th April 2015, accepted 17th May 2015

Abstract

The objective of this research work is to analyze the arsenic distribution, their possible sources in groundwater and monitoring of health consequence on human population of Kishanganj district, Bihar, India. The arsenic concentration in groundwater from different sources of five blocks of Kishanganj district, were examined during summer, rainy and winter seasons (2011-2013). In the present work the arsenic contamination varied from 0.0-22 µg/l in different groundwater resources of various villages. The result reveals that among 5 blocks of Kishanganj district 17 (11.33 %) hand pump/tap water samples have arsenic contamination above the permissible limit of 10 µg/l, whereas out of 150 open/ring wells, only 9 (6.0 %) samples were arsenic contaminated. The results of the questionnaire survey was conducted on age group from 13 to 58 years' old people in the five block of Kishanganj district to evaluate the impact of arsenic on human health. It was found that out of 1,500 participants examined, 91 (6.0 %) patients diagnosed with clinical features of arsenicosis characterized by arsenical dermal lesion. The occurrence of skin lesion was found to be high in males (3.7 %) compared to females (2.4 %)). Out of total number of cases having arsenical dermal disease, 6.0 % had pigmentation and there were no cases of keratosis. Questionnaire survey also reveals that large number of the people living in the arsenic affected villages were economically poor, had inadequate education and were engaged in physical labor and unaware of the adverse effect of arsenic contaminated water. This research study will be helpful to create awareness among the people and make them free from arsenic borne disease

Keywords: Arsenic, groundwater, impacts, human health, arsenicosis, Kishanganj district.

Introduction

Water is most abundant in living things and is absolutely essential for existence of life but unfortunately it becomes a scarce natural resource[1]. The arsenic problem is not only local and national but also global[2,3]. The ill consequence of arsenic contaminating the water reserves in the entire world is on the rise[4,5]. Arsenic has affected about 140 million people throughout the world and has the maximum number in developing countries, like ours[6,7].

In India, the first case of arsenic contamination was reported by Garai et al. in 1983 in West Bengal[8]. Chakarborti et al. reported that about 1000 villages in West Bengal are affected by arsenic contaminated water[9]. In Plains of Bihar, groundwater is the most important source of drinking and irrigation. In 2002, Barisbhan and Semaria Ojhapatti villages in Bhojpur district, and in Bihar the middle Gangetic plain, were reported having contamination exceeding 50µg/l[10]. Subsequently many chemists and biologists started examining arsenic content in water in various parts of Bihar. Ghosh et al. reported alarming results-maximum level of arsenic found were in districts of vaishali (360 ppb), Bhojpur (1860 ppb), Patna (724 ppb) and Bhagalpur (608 ppb)[11]. In early 2010, Bihar Government had acknowledged that 1618 villages in 13 districts of Bihar have arsenic in groundwater, beyond permissible levels. The most affected districts are Bhojpur, Samastipur, Buxar, Bhagalpur, Vaishali, Katihar, Khagaria, Munger, Chapra and Darbhanga.

The presence of arsenic in water is caused by natural and anthropogenic sources that depend on the local geology, hydrology and geochemical properties of aquifier substances and human activities[12]. The persistence of arsenic in water system is attributed to series of changes like redox reaction, ligand exchange and biotransformation[13]. The deposition and transporting of arsenic in aqueous water is also influenced by the pH, temperature and the presence of iron, sulfides and living things present in water bodies[13]. The redox potential and pH of water body play significant role in determining the fate and the mobilization of arsenic in water system[13].

Arsenic exists naturally in both inorganic and organic forms. Inorganic form is usually found in water as arsenate (As^{5+}), although arsenite (As^{3+}) may be present under some conditions. As^{3+} state prevails only in reducing condition as in H_3AsO_3 or anionic species as $H_2\ AsO_3^-$ while higher state (As^{5+}) in oxidizing condition and exists as $H_2AsO_4^-$and $HAsO_4^{2-}$ anions[14]. The mobility of arsenic in water is mainly due to arsenite AsO_2^-

species and As^{3+} is more toxic than As^{5+} [15].

Occurrence of arsenic exposure in human population is mainly through ingestion, inhalation and skin absorption. Inhalation of smoke of cigarette and airborne arsenic produced from industries is cause of inhalation exposure, whereas use of drinking contaminated water followed by consumption of food through irrigation, medicine and cooking is the cause of ingestion exposure[16,17]. The effect of arsenic depends upon an individual's gender, age, nutritional status, duration of exposure and finally its content in water [17,18]. Arsenic pollution may be of two types: acute poisoning and chronic poisoning[18].

Acute poisoning: Acute arsenic poisoning may occur when high doses of arsenic are ingested over short period. Symptoms of acute poisoning are: gastrointestinal effect resulting in severe vomiting and diarrhea, slow formation of red and white blood cells, damage to mucous membranes of the respiratory system and blood vessel, heart problem, swelling around the eye and thrilling sensation in hand and feet [18]. The vital doses (above 180 mg/l) can cause death[18].

Chronic poisoning: Chronic arsenic poisoning may occur when excess airborne arsenic is inhaled for a long time which effects liver, nervous and circulatory system, mucous membranes of the respiratory system and skin. Prolonged exposure to arsenic through ingestion can cause gastrointestinal effect, redness of skin, pigmentation and hyperkeratosis[17,18].

Drinking water in entire northern region of Bihar is of poor quality as it possesses different types of harmful contamination such as arsenic, fluoride and large amount of iron which poses serious threat to human life[19]. The groundwaters in some villages of Kishanganj district have been reported contaminated in various newspapers. Keeping the above facts in news, we had decided to analyze the arsenic concentration in different groundwater sources of villages in Kishanganj district.

Therefore the objective of this work is to analyze the potability of groundwater with reference to arsenic levels, in villages of Kishanganj district which will provide extensive effect of arsenic contamination in water and sources of contamination, health consequences for population of Kishanganj district.

Material and Methods

Study site: Kishanganj district is located in the north-east of the state of Bihar**,** at latitude of 25^0 20' to 26^0 30' north and longitude of 87^0 7' to 88^0 19' east. West Bengal, Nepal and Bangladesh are at border line of it. Mahananda, Kankai, Mechi, Ratwa, Ramzan and Donk are major rivers that flow through Kishanganj district. Two blocks Thakurganj and Terhagachh are located in the forest area. Two types of minerals silica and iron are found around Kishanganj district. The climate of the study area was humid with maximum temperature 42^0 C in May-June. Water samples were collected from hand pumps, tap water, open and ring wells during summer, rainy and winter seasons in the year 2011- 2013 from 30 locations of municipal area of Kishanganj block, 30 villages from 10 panchayats (3 villages from each panchayat) each of four blocks namely Bahadurganj, Kochadhaman, Teragachh and Thakurganj, covering entire Kishanganj district. The research work was carried out in laboratory of P.G. Department of Chemistry, D. S. College, Katihar (Bihar), Shiva Test House, Bailey Road, Patna, recognized as Environmental Laboratory by Central Govt. and laboratory of Kishanganj College of Engineering andTechnology Veriadangi, Kishanganj (Bihar).

Methodology: Temperature and pH were measured at the spot immediately after the collection of samples. Sulfate was measured by Gravimetric Method as recommended by UNEP, 2004 earlier given by APHA, phosphate was measured by Acid-Extraction Method as recommended by UNEP, 2004 earlier given by Environment Canada, iron was estimated by Colorimetric method described by UNEP, 2004 earlier given by Environment Canada and arsenic in drinking water was estimated by Atomic Absorption Spectrophotometer as described by A. K. De, modified by A.K. Das, earlier by Environment Canada[20]. It was important to measure temperature, pH, iron, sulfate and phosphate as they influence the concentration of arsenic content in groundwater. The mean arsenic content for each sampling site was compared with the USEPA and WHO guidelines for domestic use to assess compliance.

Results and Discussion

Arsenic Distribution: All the sampling stations (The hand pump/tap, open/ring well wise concentration of arsenic) were classified in four types as follows:

Type I : Arsenic concentration below 5 µg/l., Type II : Arsenic concentration between 5-10 µg/l., Type III : Arsenic concentration between 10-20 µg/., Type IV : Arsenic concentration between 20-50 µg/l.

The abstract of arsenic distribution in water samples from hand pump/tap and open/ring well, are tabulated in table-2 and 3 respectively. The coloured charts and pie charts are also prepared as shown in figure-3-6. Ranges of arsenic concentration in hand pump/tap water samples for Kishanganj municipal area, Bahadurganj, Kochadhaman, Teragachh and Thakurganj blocks varied from 0.0 -11, 0.0 -21, 0.0-20, 0.0-21 µg/l and 0.0-22 µg/l respectively.

Bearing this out of of 150 hand pump/tap water samples in 112 sites (76.6 %) have arsenic concentration 0-5 µg/l and fall in type-I. 21 locations (14 %) have arsenic concentration 5-10 µg/l and fall in type-II, which is the maximum desirable limit of standards for drinking water (WHO). 13 villages (8.66 %) have groundwater with arsenic concentration 10-20 µg/l and fall in type-III, which is above the maximum permissible limit of

standards for drinking water (USEPA,WHO). At this concentration patients were diagnosed with clinical features of arsenicosis characterized by arsenical dermal lesion has been observed. In 4 villages (2.67 %) arsenic concentration in groundwater is above than 20 µg/l and ≤ 50 µg/l and fall in type-IV. The consumption of arsenic per day by the population in this habitation is high and can be the cause of pigmentation and chance of pre stage of keratosis[21, 22].

The present study reveals that out of 30 samples of Kishanganj municipal area (as control) 27 (90%) samples have arsenic concentration equal or less than 5 µg/l and 02 (6.6%) have between 5-10 µg/l. and only one sample (3.3%) at S1 [(Sabir Alam) in Pachampali] has a concentration of arsenic above the current USEPA (2009) and WHO (2006) drinking water standard of 10 µg/l, whereas in Bahadurganj block 02 sites [at S10 (Gengi Tola) of Bhatabari village and at S16 (Muslim Tola) of Chanwar village], in Kochadhaman block 03 sites [at S1 (Jagir Tola) and at S3 (Dhobi Tola) of Bhag-Bssa village and at S14 (Hasim Tola) of Ghurakutt village], in Teragachh 05 locations [at S11 (Musalman Tola) and at S12 (Masthan Tola) of Dahibhat village, at S14 (Safa Tola) of Deorikhas village, at S26 (Fashim Tola) and at S27 (Haibula Tola) of Hawakol village] and in Thakurganj block 06 locations [at S1 (Kashibari) of Pawakhall village, at S3 (Teli Basti) of Dumaria village, at S9 (Gheng Ghat) of Kanak Pur vallage, at S10 (Hamla Tola) of Ambari village, at S12 (Bhatiya Basti) of Rajagaon vallage and at S21 (Purb Tola) of Malik Bati] have concentration above the pollution level 10 µg/l as per WHO (2006).

The result reveals that among 5 blocks of Kishanganj districts only 17 (11.33 %) hand pump/tap water samples have arsenic content above permissible limit of 10 µg/l, where as 133 (88.67 %) hand pumps are safe from arsenic concentration as shown pie-chart-5. Table-2 also shows that hand pump/tap water samples of all four blocks of kishanganj district were more polluted compared to municipal area (as control) with respect to arsenic contamination.

Table-1
Brief description of sampling sites

Sampling site (Block)	Distance from the first site	Panchayat -Village	Population Male Female
Kishanganj	First site	Municipal Area	55688 - 51388
Bahadurganj	25 KM north from Kishanganj town	20 - 105	10587 - 100065
Thakurganj	46 KM north from Kishanganj town	22 - 85	114109- 107960
Kochadaman	16 KM north from Kishanganj town	24 - 136	117462 -109158
Terhagachh	47 KM north from Kishanganj town	12 - 71	54837 - 52199

Figure -1
Map of Kishanganj district (from Google)

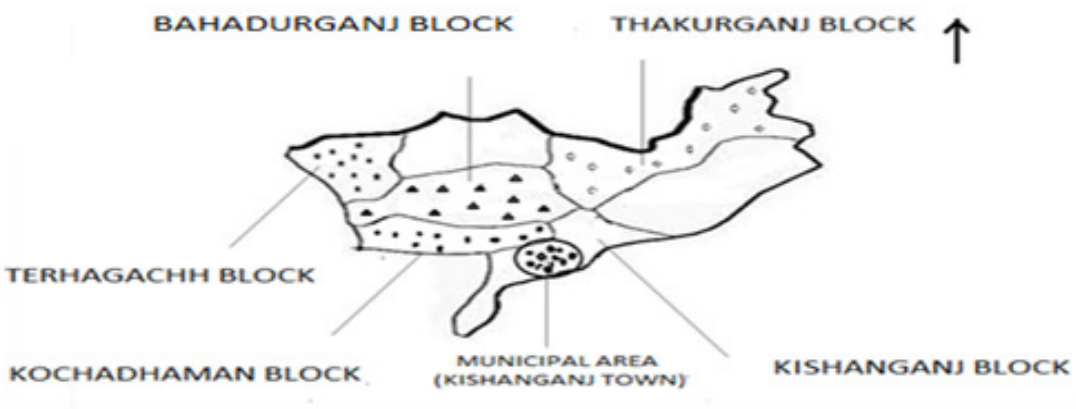

Figure -2
Sketch map of Kishanganj district showing five sampling blocks

Table-2
Abstract of Arsenic Distribution in Hand Pump/Tap Water Samples (Summer)

Block/Town	Arsenic content (µg/l)	No. of Samples with Percentage				Total no. of samples
		0-5 µg/l	5-10 µg/l	10-20 µg/l	20-50 µg/l	
Kishanganj	0.0-11	27 (90.0 %)	02 (6.67 %)	01(3.33 %)	----------	30
Bahadurganj	0.0-21	26 (86.7 %)	02 (6.67 %)	01(3.33 %)	01(1.33 %)	30
Kochadhaman	0.0-20	24 (80.0 %)	03 (10.0 %)	02 (6.67 %)	01(1.33 %)	30
Teragachh	0.0-21	19 (63.6 %)	06 (20.0 %)	04 (13.4 %)	01(1.33 %)	30
Thakurganj	0.0-22	16 (53.3 %)	08 (26.7 %)	05 (16.7 %)	01(1.33 %)	30
----------		112.0(76.7%)	21.0(14.0%)	13.0(8.66%)	04(2.67 %)	150
----------		112+21 =133.0 (88.67%)		13+4 =17.0 (11.33%)		----------

From the abstract as shown in table-3, out of 150 open/ring wells of 5 blocks of Kishanganj district tested, only 9 (6.0%) samples were arsenic contaminated. In Bahadurganj 01 (3.33%) [at S16 [(Muslim Tola) of Chanwar village], in Kochadhaman 02 (6.67%), [at S1 (Jagir Tola) of Bhag-Bssa village and at S7 (Munsi Tola) of Gurgawn village], in Teragachh 03 (10%) [at S25 (Kijleta Basti) of Hawakol village), at S26 (Fashim Tola) and at S27 (Haibula Tola) of Khajurbari village] and in Thakurganj 03 (10%) [at S3 (Teli Basti) of Dumaria village, at S9 (Gheng Ghat) of Kanak Pur vallage and at S10 (Hamla Tola) of Ambari village] of block level open/ring wells were arsenic contaminated. In Kishanganj municipal area (as control) all the open/ring wells have low level (0-6 µg/l) arsenic contamination at present as shown in figure-4.

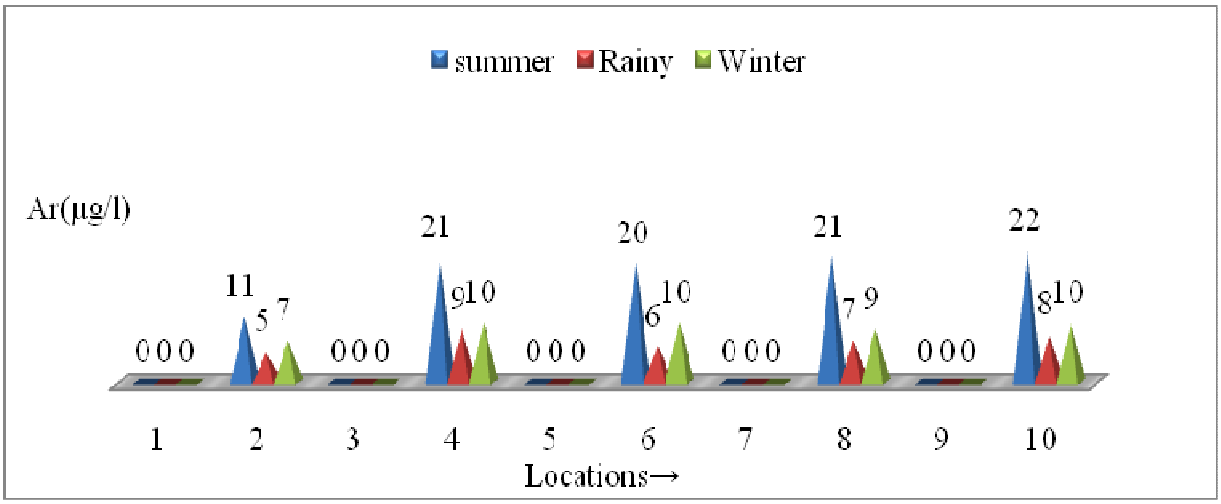

Figure -3
Graph showing seasonal variations of arsenic in hand pump/tap water samples at different locations
Table -3

Abstract of Arsenic Distribution in Open /Ring well Water Samples (Summer)

Block/Town	Arsenic content (µg/l)	No. of Samples with Percentage				Total no. of samples
		0-5 µg/l	5-10 µg/l	10-20 µg/l	20-50 µg/l	
Kishanganj	0.0-6	28.0 (93.3 %)	02 (6.67 %)	----------	----------	30
Bahadurganj	0.0-11	27.0 (90.0 %)	02 (6.67 %)	01 (3.33 %)	----------	30
Kochadhaman	0.0-11	25.0 (83.3 %)	03 (10.0 %)	02(6.67 %)	----------	30
Teragachh	0.0-20	23.0 (76.7 %)	04(13.3 %)	02 (6.67 %)	01 (3.33%)	30
Thakurganj	0.0-20	22.0 (73.3 %)	05 (16.7 %)	02 (6.67 %)	01 (3.33%)	30
----------		125 (83.3 %)	16 (10.7 %)	7.0(4.67 %)	02(1.33%)	150
----------		125+16=141 (94.0 %)		7+2=9 (6.0 %)		----------

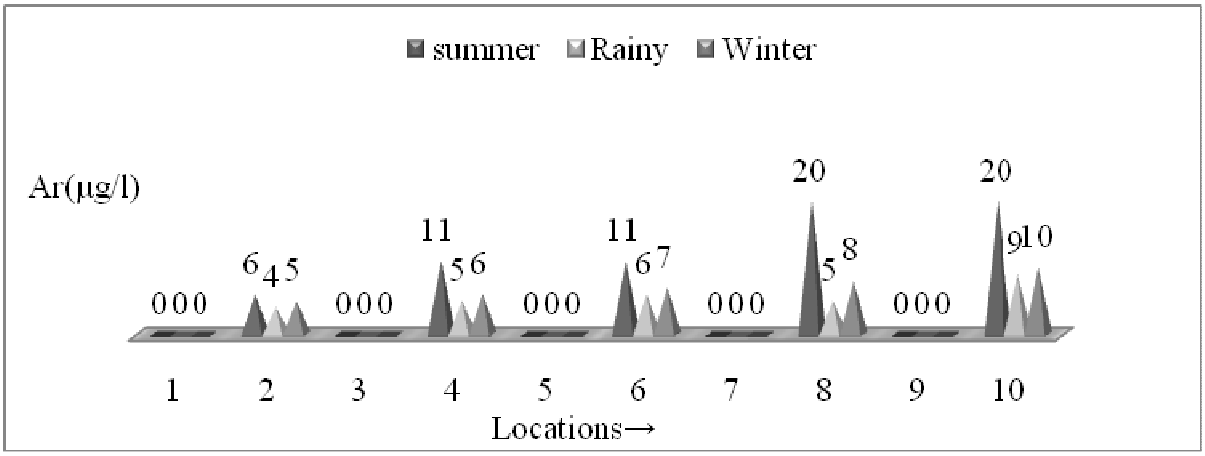

Figure-4
Graph showing seasonal variations of arsenic in open/ring well water samples at different locations

The result indicates that the level of arsenic decreases with the depth of the water tube. Till about 55 meter, the level of arsenic was high which was reduced and found in negligible quantites at the level of about 210 meters. Similar result was reported by Ghosh et al[21]. From the pie-charts as shown in figure- 5 and 6 and abstracts as shown in table-2 and 3, it is clear that open/ring well water samples are more safe compared to hand pump/tap water samples with respect to arsenic contamination at present.

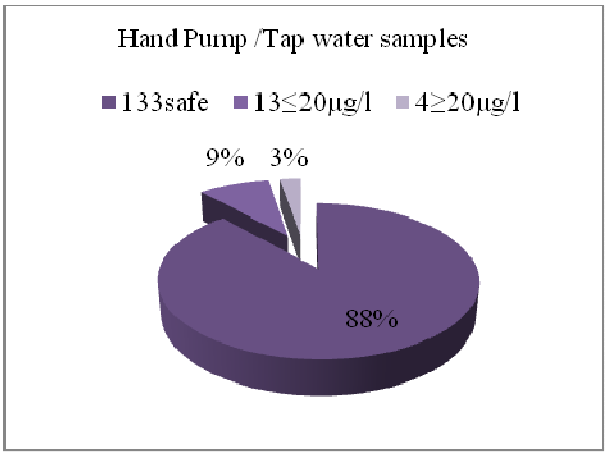

Figure- 5
Arsenic toxicity in the hand pump/tap water samples
Chemical and Physical Control

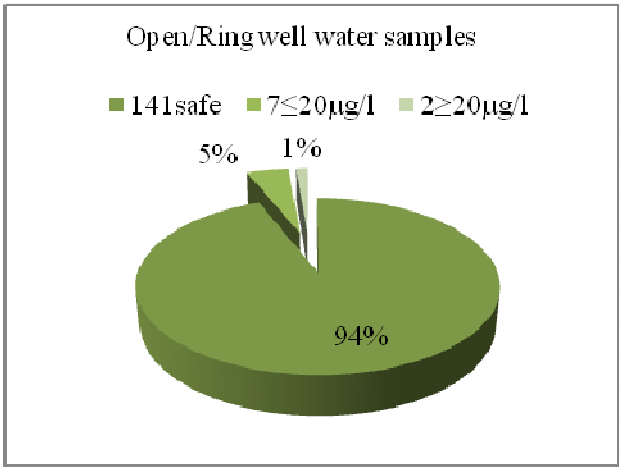

Figure-6
Arsenic toxicity in the open/ring well water samples
Chemical and Physical Control

The factors that affect the presence of arsenic in groundwater include availability of iron oxide, high pH, and anion such as sulfate, phosphate and area of extreme evaporation of water system. Another factor such as age of water bodies, mineralogy of aquifer materials and the geochemistry of water bodies also affect the persistence of arsenic in groundwater.

Correlation between pH and arsenic relation: pH is the most

important controlling factor of presence of arsenic in water system[22]. The content of arsenic in water is generally high (>10 µg/l), having high value of pH ≥8 in groundwater. In the present study pH at all the sampling sites varied from 6.2-8.9, 6.1-8.7, 6.1-8.8, 6.1-8.8, and 7.1-8.9 in the hand pumps/taps and 6.2-8.6, 6.2-8.8, 6.2-8.7, 6.1-8.7 and 7.2-8.8 in open /ring wells of municipal area of Kishanganj, Bahadurganj, Kochadhaman, Teragachh and Thakurganj block respectively. The reaction between iron minerals and water at alkaline medium produce higher arsenic concentration in groundwater[23, 24]. Deposition of arsenate (As^{5+}) increases at progressively higher pH in presence of iron oxide and clay minerals[24, 25]. Iron is found at all locations of Kishanganj district. From the comparative study as shown in figure-7-10, the values of pH and iron are generally high in summer at most of the sampling stations as they may cause increase in arsenic concentration in groundwater. At higher pH desorption of arsenite (As^{3+}) is also a function of pH.

Correlation between iron and arsenic concentrations: Iron is naturally occurring element in earth. When water passes through rock and soil it can dissolve these minerals and carry them into water bodies. Corrosion and deterioration of old iron pipes may also be source of iron in water. It was observed that iron content varied from 0.21-0.61 mg/l, 0.21-0.65 mg/l, 0.11-65 mg/l, 0.18-0.62 mg/l and 0.12-0.63 mg/l in all hand pump/tap and 0.11-0.45 mg/l, 0.11-0.45 mg/l, 0.11-0.51 mg/l, 0.11-0.33 mg/l and 0.11-0.37 mg/l in all open/ring well water samples of Kishanganj municipal area, Bahadurganj, Kochadhaman, Teragachh and Thakurganj block respectively. The persistence of arsenic in water system is also affected by the occurrence of iron in aqueous solution[26]. Adsorption and co-precipitation of arsenic on iron oxide is affected by pH and quantity of iron oxide and concentrations of competing ions present in water[26,27]. The result reveals that high concentration of arsenic in summer season is due to high content of iron in summer in most of the sampling sites as shown in figure-9 and 10.

Correlation between phosphate, and arsenic concentrations: Phosphorus enters into groundwater by excess use of phosphate fertilizers, seepage of domestic sewage, detergent and flow of industrial effluents. The presence of phosphate in the study area was found in the range of 0.03-1.51 mg/l, 0.06-1.52 mg/l, 0.07-1.50 mg/l, 0.06-1.53 mg/l, 0.11-1.42 mg/l, in hand pumps/taps and 0.02-1.36 mg/l, 0.05-1.39 mg/l, 0.07-1.25 mg/l, 0.10-1.27 mg/l, 0.11-1.16 mg/l in open/ring wells of Kishanganj municipal area, Bahadurganj, Kochadhaman, Teragachh and Thakurganj block respectively. The relation of arsenic with dissolved phosphate in groundwater in alkaline medium was reported by various researchers[28,29].The use of phosphate fertilizers onto soil water is major role for releasing arsenic in groundwater and that can increase arsenic concentrations in groundwater by releasing adsorbed arsenic[29]. The result reveals that all water samples have low concentration of phosphate as shown in figure-11 and 12, suggesting that its presence does not have remarkable effect on arsenic concentration in groundwater.

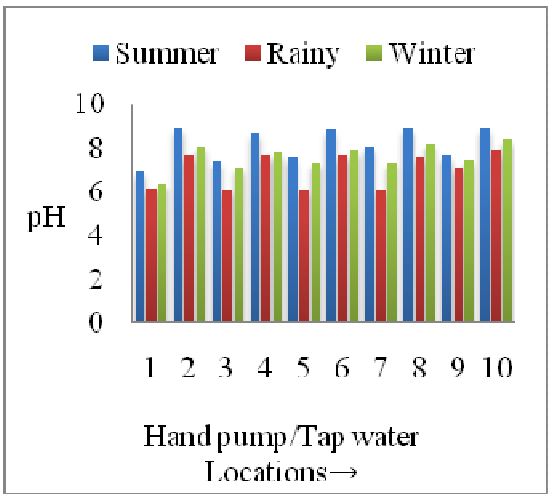

Figure-7
Graph showing seasonal variations of pH

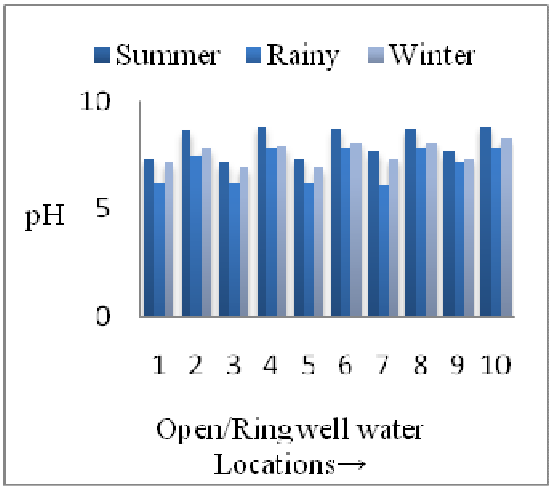

Figure-8
Graph showing seasonal variations of pH

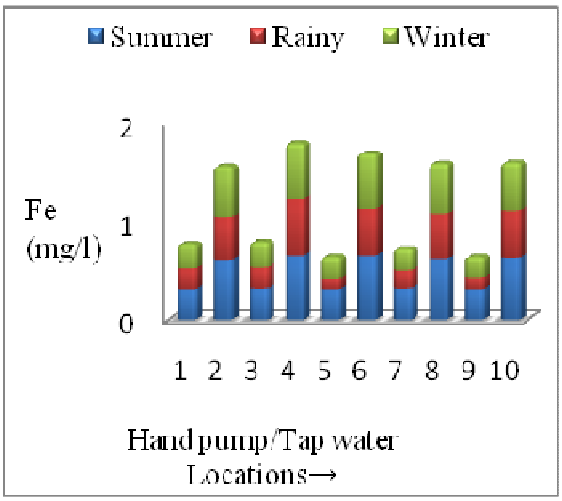

Figure-9
Graph showing seasonal variations of iron

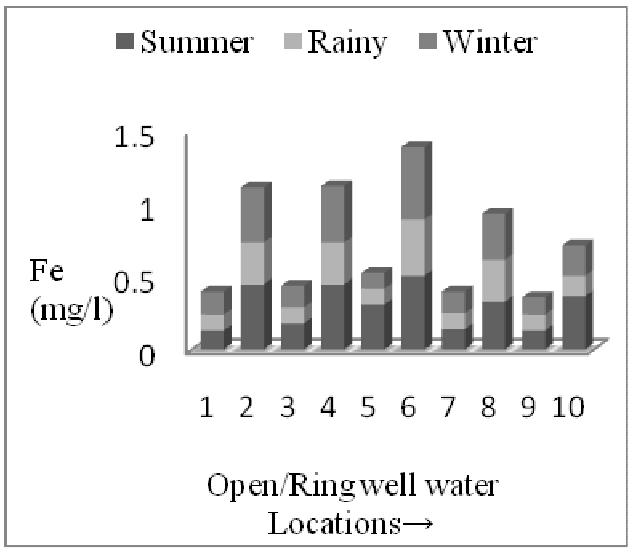

Figure-10
Graph showing seasonal variations of iron

Correlation between sulfate and arsenic concentrations: The presence of sulfate anion in groundwater is also a factor that can affect arsenic concentration in water system [30]. The concentration of sulfate was in the range of 45-157 mg/l, 20-77.2 mg/l, 43-92.4 mg/l, 40-99.5 mg/l, 42-98.5 mg/l, in hand pumps/taps and 56-99.8 mg/l, 23-95.2 mg/l, 42-96.2 mg/l, 34-98.4 mg/l, 44-88.4 mg/l in open/ring wells water samples of Kishanganj municipal area, Bahadurganj, Kochadhaman, Teragachh and Thakurganj block respectively. The result shows that concentration of sulfate ion is relatively lower than permissible limit (WHO, 2006) at all sampling locations as shown in figure-13 and 14, suggesting that its appearance probably does not have great effect on arsenic concentration in groundwater.

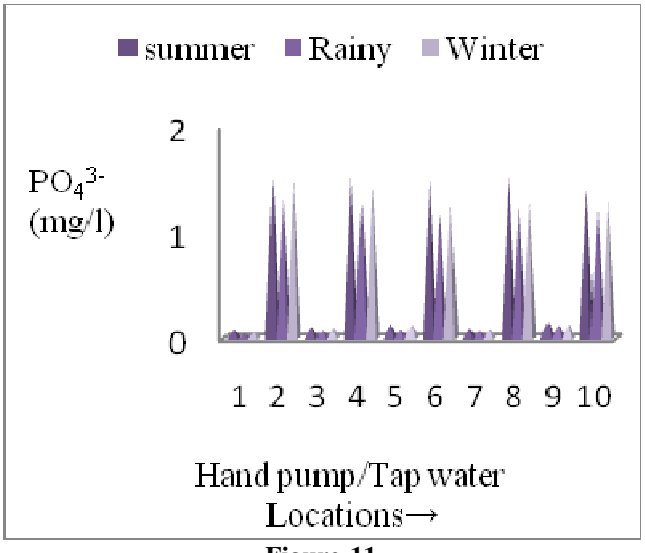

Figure-11
Graph showing seasonal variations of phosphate

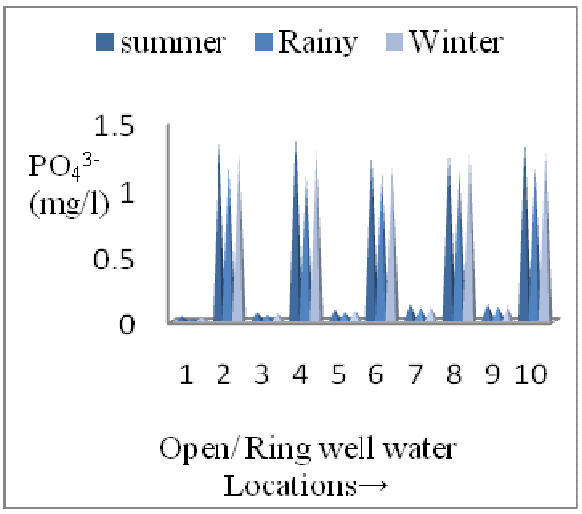

Figure-12
Graph showing seasonal variations of phosphate

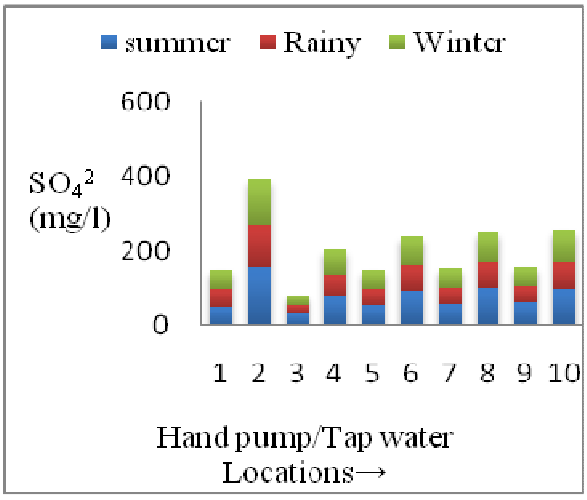

Figure-13
Graph showing seasonal variations of sulfate

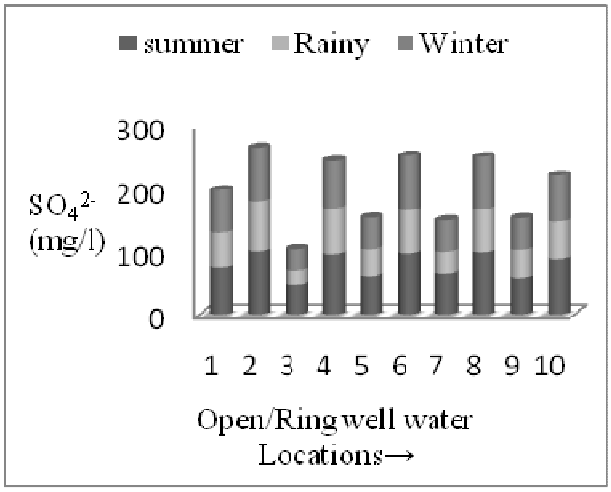

Figure-14
Graph showing seasonal variations of sulfate

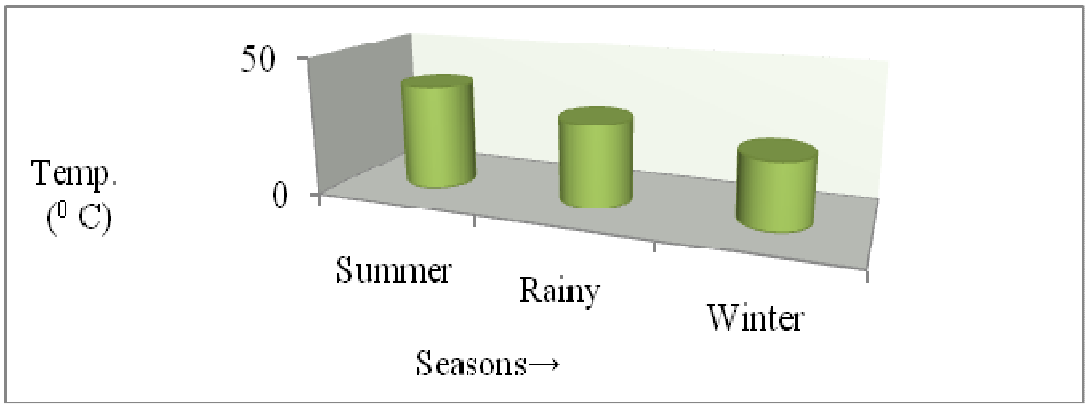

Figure-15
Graph showing mean temperature values

Arsenic in areas of high evaporation: The maximum average temperature in Kishanganj district during summer, rainy and winter were 38^0C, 30^0C and 24^0C respectively. In summer season water evaporation appears to be the deciding factor to produce high arsenic concentrations. Thermal waters especially those of high pH are rich in arsenic. Wet seasons have relatively low temperatures associated with low arsenic availability as observed. Though the temperature values in summer are higher than those in rainy and winter season, their arsenic concentrations throughout the sampling period are generally high and comparable as shown in figure-2 (hand pumps) and figure-3 (open wells). Similar trend of studies has been has been reported by Alan H. Welch et al.

Evaluation of Impact of Arsenics on Human Health based on questionnaire: The results of the questionnaire survey was conducted on age group from 13 to 58 years' old people in the 10 locations of Kishanganj town and 40 panchayats of rural area in four blocks of Kishanganj district to evaluate the impact of arsenic on human health . On the basis of their living status, their source of drinking and cooking water and duration of exposure of such water, 1,500 people were selected for interview and clinical test. Clinical test was performed during 2011- 2013 with help of dermatologists who are regularly in practice, since 8-10 years in Kishanganj district and patients who were regularly under medical treatment in private, government hospital and the Kishanganj Medical College and Hospital. The occurrence and severity of Pigmentation and Keratosis was examined on the basis of dermatological criteria as follows[7].

Pigmentation clinical grading: Mild-I: Scanty pigmentation resulting leucomelanosis, Moderate-II: Deeper pigmentation, Severe -III: Deep and dark pigmentation generally under tongue surface and lining of cheeks,

Keratosis clinical grading: Mild–I : Thickening of skin with elevations in palms and soles, Moderate –II : Skin thickening with raised keratosis in palms and soles, Severe-III: More thickening with serious keratotic elevations in palms soles and extremes of dorsal points.

The present survey reveals that out of 1,500 people 91 (06%) people were suffering from skin disease of pigmentation of grade-I, and no cases were observed in grade II to III of pigmentation and of keratosis grading as shown in table-4. It was also observed that out of 91 patients, 10 (3.3%) belonged to municipal area and 14 (4.7%), 20 (6.7%), 22 (7.3 %) and 25 (8.3%) were of Bahadurganj, Kochadhaman, Teragachh and Thakurganj block of Kishanganj district respectively. The result shows that the percentage of males (3.7%) affected were greater than the females (2.4%). The similar case was reported by Mazumdar et al. in India (2010).

Table-4
Occurrence of Pigmentation

Examined Block/Town	Total No. of case	Affected cases		Unaffected cases	Pigmentation (%)			Occurrence (%)
		Male	Female	0	I	II	III	
Kishanganj	300	07	03	290 (53.2%)	10(3.3)	----	--	3.33
Bhadurganj	300	07	05	286 (46.6%)	14(4.7)	----	---	4.67
Kochadhaman	300	13	10	280 (45.8%)	20(6.7)	----	---	6.67
Tteragachh	300	12	11	278 (44.2%)	22(7.3)	----	---	7.33
Thakurganj	300	14	11	275 (42.2%)	25(8.3)	----	---	8.33
Total	1,500	55(3.7%)	36 (2.4%)	1409 (93.9%)	91(6.0)	----	---	6.07

Conclusion

It is concluded that in the current study the arsenic concentration varied from 0.0-22 µg/l in hand pumps/tap and 0.0-20 µg/l in open/ring well water samples of various villages in five blocks of Kishanganj district. High iron concentration, high pH and high temperatures of the study area may contribute to high arsenic concentrations in groundwater. Questionnaire survey also reveals that a large number of the people living in the arsenic affected areas were economically poor, had inadequate education and were engaged in physical labor and were unaware of the adverse effect of arsenic contaminated water. This research study could be helpful for Governmental and non-Governmental agencies to take steps in eradicating arsenicosis by creating awareness among the people and make them free from arsenic borne disease.

References

1. Kumar A. and Kumar V., Fluoride Contamination in Drinking Water and its Impact on Human Health of Kishanganj, Bihar, India*, Res. J. Chem. Sci.,* **5(2),** 76-84 **(2015)**

2. Srivastava A., Arsenic-21st Century Calamity- A Short Review, *Res. J. Recent. Sci.,* **3**(**ISC-2013**), 7-13 **(2014**)

3. Yadav G., Pandey D. N. and Patel D. K., Assessment of Ground Water Quality and its Impact on Health of people around Rewa City, MP, India, *Int. Res. J. Environment Sci.,* **3(7)**, 70- 72 **(2014)**

4. Gupta S. and Gupta V., Speciation and Toxicity of Arsenic: A Human Carcinogen, *Res. J. Recent. Sci.,* **2(ISC-2012**), 45-53 **(2013)**

5. Choudhury M., Paul C. and Kamboj N., Potable Water is a Serious Environmental Issue: A Special Study on Umiamm Area, of Ri-Bhoi District, Meghalaya, India, *Int. Res. J. Environment Sci.,* **3(9)**, 37-42 **(2014)**

6. Chakraborti D., Rahman M. M., Paul K., Sengupta M.K., Chowdary U.K. and Lodh D. et.al., Arsenic calamity in India and Bangladesh sub-continent whom to blame?, *Talanta*, **58**, 3-22 **(2002)**

7. Guha Mazumdar D. N., Ghosh A., Mazumdar K. K., Ghosh N., Saha C. and Guha Mazumdar R.N., Aerenic Contamination of Ground Water and its Health Impact on Population of District of Nadia, West Bengal, India, *Indian J Community*, **35(2)**, 331-338 **(2010)**

8. Garai R., Chakraborty A.K., Dey S.B. and Saha K.C., Chronic arsenic poisoning from tube well water, *J. Indian Med. Assoc*., **82**, 34-35 **(1984)**

9. Chakraborty D., Samanta G. et al., Arsenic in Groundwater In Six Districts of West Bengal, India: Biggest arsenic Calamity in the World*, Environ. Geochemistry and Health*, **18,** 5-15. **(1994)**

10. Chakraborti D., Mukherjee S. C., Pati S, Sengupta M. K,, Rahman M. M., Chowdhury U. K., et al., Arsenic Groundwater Contamination in Middle Ganga Plain, Bihar, India: A Future Danger, *Environmental Health Perspective,* **111 (9),** 1194- 1201 **(2003)**

11. Ghosh A. K., Singh S.K., Bose N. and Chaudhary S., Arsenic contaminated aquifers: a study of the Ganga levee zones in Bihar, India, Annual Conference, Royal Geographical Society, London, Session, key: BSG-session 3, Paper-5 , 29-31 August **(2007)**

12. Welch A.H., Westjohn D.B., Helsel D.R. and Wanty R.B., Arsenic in groundwater of the US: Occurrence and Geochemistry , *Ground Water*, **38,** 589-604 (**2000**)

13. Bruce J. L., Michael F.H., Janie H. and Monty C.D., Drinking Water Problems, Texas A and M Agrilife Extension Service, L-5467, 11-05,

14. Ananta S., Banerjee S. and Veer V., Adsorption Isotherm, Thermodynamic and Kinetic Study of Arsenic (III) on Iron Oxide Coated Granular Activated Charcoal, *Int. Res. J. Environment Sci.,* **4(1),** 64-77 **(2015)**

15. Raven K.P., Jain A. and Loeppert R.H., Arsenit and arsenate adsorption on ferrihydrite: Kinetics, equilibrium, and adsorption envelopes. *Environmental Science and Technology,* **32(3),** 344-349 (**1998**)

16. Muherjee A., Sengupta M. K., Hossain M.A., Ahamed S., Das B. and Nayak B., Arsenic contamination in groundwater a global perspective with emphasis on the Asian scenario, *Journal of Health and Population Nutrition,* **24,** 142-163 **(2006)**

17. Khan M. M.H., Aklimunnessa K., Kabir M and Mori M., Determinants of drinking arsenic contaminated inated tube well water in Bangladesh, *Health Policy Planning,* **22**, 335-343 **(2007*)***

18. Holque S.R., Arsenic Pollution in Rural West Bengal-Exploring Some Challenges, *IOSR-Journal Of Environ. Sci. Toxicology and Food Technology*, **2(6),** 13-17 **(2013)**

19. Kumar A., Singh M.K. and Renu N., Studies on Fluoride, Arsenic and Heavy Metal contamination in Drinking Water of Katihar District, Bihar with reference to its Impect on Human Population . National Seminar sponsored by C.S.I.R, B.C.S.T. and co-sponsored by Indian Chemical Society, Kolkata and conducted by G.B. College Naugachia on 21st to 22nd, page- 114-124, September, **(2010)**

20. UNEP., Analytical Method for Environment Water Quality; UNEP GEMS /Water Program and IAPE (1985), code-16301 page-60, code-115903 page-60, code -26104 page 87, code- 33007, 101 **(2004)**

21. Ghosh A.K., Kroesen J.O., Bose N. and Kumar R., Dealing with arsenic in rural Bihar, India, **(2013)**

22. Smedley P.L. and Kinniburgh D.G., A review of the

source, behaviour and distribution of arsenic in natural waters, *Appl. Geochem.,* **17,** 517-568 (**2002**)

23. Masscheleyn P.H., Delaune R.D. and Patrick Jr W.H., Arsenic and selenium chemistry as affected by sediment redox potential and pH, *Journal of Environmental Quality*, **20(4),** 446-456 **(1991)**

24. Johnson C.A. and Thornton I., Hydrological and chemical factors controlling the concentrations of Fe, Cu, Zn and As in a river system contaminated by acid mine drainage, *Water Research,* **21(3),** 359-365 **(1987)**

25. Welch A.H. and Stollenwerk K.G., In Arsenic in Ground Water: Geochemistry and Occurrence; Eds.; *Kluwer Academic Publishers: Boston,* **46,** 67-100 (**2003**)

26. Davis J. A., Fuller C.C., Rea B.A. and Claypool-Frey R.G., Sorption and coprecipitation of arsenate by ferrihydrite*, In Water-Rock Interaction*, ed. D.L. Miles, 187-189, Rotterdam: Balkema, (**1989**)

27. Belzile N. and Tessier A., Interactions between arsenic and iron oxyhydroxides in lacustrine sediments, *Geochimica et Cosmochimica Acta*, **54,** 103-109 (**1990**)

28. Woolsen E.A., Axley J.H. and Kearney P.C., The chemistry and phytotoxicity of arsenic in soils: II, Effects of time and phosphorous, *Soil Science Society America Proceedings,* **37(2),** 254-259 (**1973**)

29. Davenport J.R. and Peryea F.J., Phosphate fertilizers influence leaching of lead and arsenic in a soil contaminated with lead and arsenic in a soil contaminated with lead arsenate, *Water, Air and Soil Pollution,* **57-58**, 101-110(**1991**)

30. Moore J.N., Ficklin W.H. and Johns C., Partitioning of arsenic and metals in reducing sulfidic sediments. *Environmental Science and Technology*, **22**, 432-437 (**1988**)