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Assessment of Arsenic in Groundwater of Gorakhpur District in Uttar Pradesh (India)

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***Abstract*— Assessment of arsenic along with some other significant water quality parameters was analyzed in ground water of the study area during April to August, 2011. Total 248 samples were collected from different parts of the district in which 29.84% of the groundwater samples were found arsenic concentration in the range of 10-50 ppb and 6.45% of the samples were above 50 ppb. Thus, total 36.29% samples were recorded as arsenic more than the WHO standards of 0.01 mg/l or 10 ppb. The maximum arsenic concentration 91 ppb was found in Khorabar block and the situation is alarming in 4 blocks of the district namely Piprauli, Barhalganj, Khorabar and Jungle Kauria where more than 50% of the samples were found to be non-compliant. The study of the arsenic with respect to other water quality parameters like alkalinity, pH, hardness, calcium, magnesium, iron, depth of source and distance from river of the source has indicated some clues about its relationship with iron, calcium, alkalinity and hardness in some blocks but no definitive trends are observed. The results revealed that the peoples of Gorakhpur are at risk while consuming groundwater for drinking purpose.**

***Keywords*- arsenic, groundwater, hand pumps, Gorakhpur.**

I. INTRODUCTION

With exponentially increasing population of the country and deterioration in water quality of most of the surface water bodies in the country the dependence on groundwater to meet the water demand has grown over the last several years. Most of the rural and urban population is presently using ground water for drinking purpose and there is a very little awareness and emphasis on the quality of drinking water. However, with high exploration rate of groundwater and lowering of groundwater table the dependence of groundwater in deep aquifers is increasing. Generally, it is believed that the water quality from deep bore wells and India Mark-II hand pumps would be safe and wholesome but the reports about the occurrence of arsenic in such waters have lead to a deep concern among the scientific circles, the public at large is still poorly aware about the nature and magnitude of the problem. Therefore, groundwater arsenic contaminations posses' serious health hazards to a large section of communities all over the world.

Arsenic contamination in groundwater is widely studied in India and its neighbouring countries. Jakhrani et al. 2009 reported high arsenic level in groundwater of Khairpur, Pakistan, while Safiuddin and Karim 2001 have reported that the serious arsenic contamination of groundwater in Bangladesh has come out recently as the biggest natural calamity in the world. Further, Dipankar Chakraborti et al. 2009 mentioned in his report that in West Bengal alone, 26 million people are potentially at risk from drinking arsenic-contaminated water. Groundwater arsenic contamination was also reported in the Terai area of Nepal in 2001. In 2003, a report on arsenic groundwater contamination in the Middle Ganga Plain of the state of Bihar in India was published. More recently discovery of arsenic groundwater contamination in the Uttar Pradesh and Jharkhand states in the Gangetic plain and the state of Assam in the Brahmaputra plain of India had also took place. It appears that a good portion of all states and countries in the Ganga-Meghna-Brahmaputra (GMB) plain, comprising an area over 500,000 km^2 and a population over 450 million may be at risk from groundwater arsenic contamination. Arsenic contamination in groundwater of India was first reported in 1976 from Chandigarh and different villages of Punjab, Haryana and Himachal Pradesh.

The literature review has indicated that the assessment of arsenic in groundwater is of paramount importance and the detail study of arsenic in groundwater of Gorakhpur district has not been attempted. As the source of water supply in

Gorakhpur district is groundwater only, such an assessment will be able to provide insight into the present status of arsenic in groundwater that could cause the health hazards above the permissible limit and need for suitable removal methodologies towards protecting public health from the adverse effects of arsenic after prolonged use in future.

II. STUDY AREA

Gorakhpur (Latitude 26º 13' N and 27º 29' N and Longitude 83º05' E and 83º56' E) is one of the eastern district of Uttar Pradesh, India has geographical area 3,483.8 sq. km with average temperature ranging from 20 ^{0}C to 31 ^{0}C and an annual average rainfall is between 1016 mm to 1207 mm. Rapti river is the major river of the district originating from Nepal that sometimes caused severe floods. The Rapti is interconnected through many other small rivers following meandering courses across the Gangetic plain.

The geology of the district exposes nothing beyond ordinary river borne alluvium which is not old. The mineral products are few and unimportant. Brick clay is abundant everywhere and bricks are made all over the district. The soil in the district is light sandy or dense clay of yellowish brown colour. The sand found in the rivers is medium to coarse grained, greyish white to brownish in colour and is suitable for construction. The study area comprising 9 blocks namely Barhalganj, Brahmpur, Campierganj, Jugle Kauria, Kauriram, Khorabar, Piprauli, Sahjanwa, Sardar Nagar and city of Gorakhpur district is shown in Fig. 1.

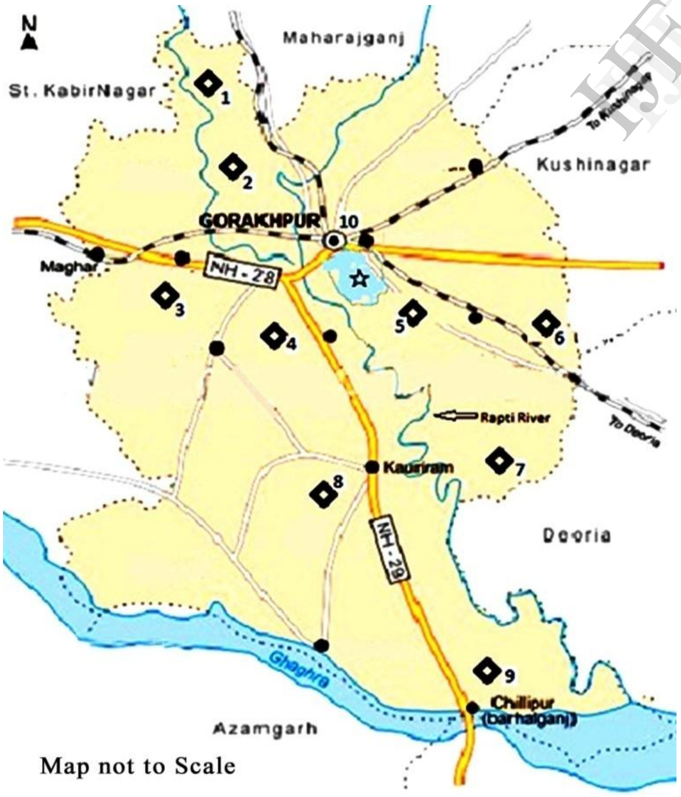

Fig. 1. Study Area

III. MATERIALS AND METHODS

The water samples of selected sites were taken from groundwater sources and tested in Environmental and P. H. E. Laboratory of Madan Mohan Malaviya Engineering College, Gorakhpur for their arsenic concentration and some other physical and chemical characteristics. The samples from nine blocks of Gorakhpur district was collected during pre-monsoon period whereas the samples from Gorakhpur city was collected and analyzed during the months of June and July, 2011. The sites for the sources of sample collection decided on the basis of such sources where groundwater was being used for drinking purposes. Barring a few, the samples were mostly taken from India Mark-II hand pumps installed by Uttar Pradesh Jal Nigam.

The samples were collected in clean polyethylene bottles of 1 litre capacity after five minutes pumping of hand pump and rinsed twice with a portion of the sample which brought immediately to the laboratory for further analysis. All precautionary measures were taken during transportation of samples.

The analysis was carried out in accordance with the standard procedure. The results so obtained were subjected to the comparison with the standards prescribed for respective parameters by IS: 10500-1991 and WHO.

Considering that the determination of Arsenic requires sophisticated instruments and laborious laboratory practices, an Arsenator developed by Wagtech International, U. K. made available by Uttar Pradesh Jal Nigam as a part of support to carry out the research work. Notably, it is so portable that the Arsenic detection could be done in the field also. Arsenator has an arsenic detection range from 1 ppb to 500 ppb and if the test result reads above 500 ppb dilution tube is used with de-ionised water and the result is converted accordingly.

Fig. 2. An Arsenator

IV. RESULTS AND DISCUSSION

The samples of groundwater tested for Gorakhpur district block-wise scenario along with that in Gorakhpur city showing acceptable (< 1 to <10 ppb), moderate (between 10-50 ppb) and high (> 50 ppb) concentration of arsenic is summarized in Table 1 and Table 2 and relative situation is depicted in Fig. 3. It is revealed that all the samples in Sahjanwa block are found within the norms whereas in Sardar Nagar, Gorakhpur city, Kauriram, Campierganj and Brahmpur more than 50% samples were found within norms. However, the situation in Piprauli, Barhalganj, Khorabar and Jungle Kauria is alarming as more than 50% of the samples were found to be non-compliant.

Table 1: Arsenic Concentration in Samples

Block Name/City	Total Number of Samples	Arsenic Concentration			Maximum Observed Arsenic Concentration (ppb)
		< 1 to < 10 ppb	*10 to 50 ppb*	*> 50 ppb*	
Barhalganj	14	2	11	1	63
Brahmpur	23	14	5	4	56
Campierganj	40	26	11	3	74
Jungle Kauria	18	8	10	0	40
Kauriram	16	12	4	0	39
Khorabar	20	5	10	5	91
Piprauli	18	1	14	3	63
Sahjanwa	10	10	0	0	9
Sardar Nagar	19	18	1	0	15
City	70	62	8	0	47
Total	248	158	74	16	
Percentage	100	63.71	29.84	6.45	

Table 2: Arsenic Concentration range in terms of Percentage

Block Name/City	Arsenic Concentration < 1 to < 10 ppb	Arsenic Concentration 10 to 50 ppb	Arsenic Concentration > 50 ppb
Barhalganj	14.3	78.6	7.1
Brahmpur	60.9	21.7	17.4
Campierganj	65	27.5	7.5
Jungle Kauria	44.4	55.6	0
Kauriram	75	25	0
Khorabar	25	50	25
Piprauli	5.6	77.8	16.6
Sahjanwa	100	0	0
Sardar Nagar	94.7	5.3	0
City	88.6	11.4	0

The evaluation of arsenic concentration in 248 groundwater samples of Gorakhpur district, Uttar Pradesh, India has provided useful insight into the extent of arsenic toxicity in the study area. It was found that arsenic concentration in 90 samples taken from India Mark-II hand pumps was higher than the permissible limit of 10 ppb. With this in view, a detailed investigation about local sources of arsenic and mechanisms of arsenic release is required.

About 29.84% of the groundwater samples were arsenic concentration in the range of 10-50 ppb and 6.45% of the samples were above 50 ppb. Thus, total 36.29% samples were found arsenic more than the permissible limit during the study. A glance at Table 2 reflects that the installation of arsenic removal units is compulsorily required at such hand pumps where arsenic is more than the permissible limit.

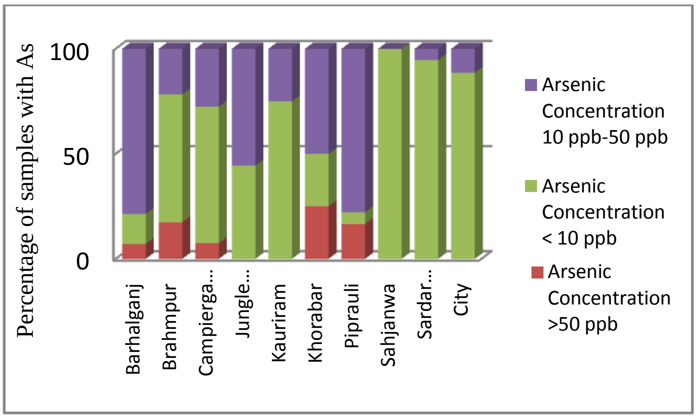

Fig. 3. Arsenic Concentration range

The interferences has been made suitably for arsenic with respect to other water quality parameters like alkalinity, pH, hardness, calcium, magnesium, iron, depth of source and distance from river of the source has indicated some clues about its relationship with iron, calcium, alkalinity and hardness in some blocks but no definitive trends are observed.

The study of variation of arsenic in groundwater with respect to depth of source, even though subjective in nature has revealed that the high arsenic concentrations are mostly obtained from the samples taken from depth 30 meters or more. This leads to a conjecture before the consumer whether to have arsenic free contaminated water from shallow depth or contamination free high arsenic water from deep aquifers.

Additionally, with a view to ascertain the presence of arsenic some water samples from Rapti and Rohin rivers and a sample of sediment bed from Rapti river was also collected and analysed for arsenic concentration, whose results are given in Table 3.

Table 3: Results and Analysis of Sample taken from Rapti and Rohin Rivers

S. No.	Source	Location	Sample	Arsenic Concentration (ppb)
1	Rapti River	Upstream at Rajghat bridge	Surface Water	0
2	Rapti River	Downstream at Rajghat bridge	Surface Water	0
3	Rapti River	Rajghat bridge	Sediment Bed	15
4	Rohin River	Downstream at Railway bridge	Surface Water	0

Table 3 reveals that the rivers are not carrying arsenic in water flowing into it. However, the presence of arsenic 207.53 mg/kg of dry bed sediments may be attributable to some anthropogenic sources of arsenic and further investigations in this direction may be required.

In addition to above findings, it is believed that the over exploitation of ground water leading to fast depletion of groundwater table may be the main cause behind the release of arsenic from deep strata leading, thereby, to the spreading of arsenic problem in groundwater in Gorakhpur district over a period of past several years. The proposition is found on the fact that intermittent incidents of arsenic contamination in groundwater can arise both naturally and industrially. The natural occurrence of arsenic in groundwater is directly related to the arsenic complexes present in soils. Arsenic can liberate from these complexes under some circumstances. Since arsenic in soils is highly mobile, once it is liberated, it results in possible groundwater contamination. The researchers also inferred that, although arsenic is occurring in the alluvial sediments, the ultimate origin of arsenic is perhaps in the outcrops of hard rock's higher up the Ganges catchment.

Presently, there are *two well-known theories* about the mechanism of arsenic contamination in groundwater. These are *oxidation* and *oxyhydroxide reduction* theory. The oxidation theory is so far the accepted theory. According to this theory, arsenic is released from the sulfide minerals (arseno-pyrite) in the shallow aquifer due to oxidation. The lowering of water table owing to over exploitation of groundwater for irrigation has initiated the release of arsenic. The large-scale withdrawal of groundwater has caused rapid diffusion of oxygen within the pore spaces of sediments as well as an increase in dissolved oxygen in the upper part of groundwater. The newly introduced oxygen oxidizes the arseno-pyrite and forms hydrated iron arsenate compound known as pitticite in presence of water. This is very soft and water-soluble compound. The light pressures of hand pump water break the pitticite layer into fine particles and make it readily soluble in water. Then it seeps like drops of tea from the teabag and percolates from the subsoil into the water table. Hence, when the hand pump is in operation, it comes out with the extracted water. According to oxyhydroxide reduction theory, arsenic is derived by desorption from ferric hydroxide minerals under reducing conditions. Ferric hydroxide minerals are present as coatings in the aquifer sediments. In anaerobic groundwater, these sedimentary minerals release its scavenged arsenic.

The oxidation of arseno-pyrite could be the main mechanism for the groundwater arsenic contamination in Gorakhpur but there is not enough hydrological and geochemical data to validate the process completely. The validity of oxyhydroxide reduction theory is also questionable due to the lack of comprehensive sampling and systematic analysis of iron oxy-hydroxides in the affected areas.

It may be worthwhile to extract samples of core water from the aquifers in the affected area with a view to look into the various possibilities of arsenic release in ground water.

V. RECOMMENDATIONS AND CONCLUSION

The contamination of arsenic in groundwater has emerged as one of the most prominent problems being faced by public health engineering department, in particular and public at large in both urban and rural areas. The assessment of the arsenic concentration in groundwater in Gorakhpur district revealed the following recommendations and conclusions:

1. The evaluation of arsenic concentration in 248 groundwater samples of Gorakhpur district, Uttar Pradesh, India has provided useful insight into the extent of arsenic toxicity in the study area. It was found that arsenic concentration in 90 samples taken from India Mark-II hand pumps was higher than the permissible limit of 10 ppb. With this in view, a detailed investigation about local sources of arsenic and mechanisms of arsenic release is required.

2. The use of groundwater for drinking purposes from arsenic contaminated identified hand pumps should be restricted till the installation of arsenic removal filters in near future.

3. Presence of arsenic in bed sediments of Rapti river and some trends of lowering of arsenic concentrations in groundwater with respect to the distance from river, even though subjective in nature, indicates the possibility of the flow of arsenic bearing sediments from the Himalayan rocks or some anthropogenic pollution about which further investigations are required.

4. An "Arsenic Support Cell" fully equipped with adequate test facilities, mobile van and trained staff may be established at district level to take up arsenic related problems on high priority.

5. Reliable testing facilities and field kits should be made available to the people at reasonable cost.

6. Any plan for abstraction from deep aquifer should be subjected to monitoring of both the quality and quantity of the available resources and there should not be any abstraction from deeper aquifers for irrigation purposes. Abstraction from deep aquifer can be made if only a distinct clay layer separates the shallow and deep aquifer and keeps the deep aquifer safe for a considerably long period.

7. The construction of deeper hand pumps should be made with adequate precaution against cross contamination.

8. Initiatives need to be taken to popularize rainwater harvesting and ground water recharge in the arsenic affected areas. Increasing the green cover and plantations may also prove to be useful in long run.

It may, therefore, be concluded that the ground water in Gorakhpur district is affected by arsenic at many places and extensive water quality survey is needed to ascertain the sources which are arsenic free and also those where arsenic removal units are required. Adequate attention is also needed towards ensuring public participation and motivation for mitigating the risk from arsenic contamination in ground water

It is, therefore, necessary to adopt an integrated approach towards groundwater quality management on the basis of existing groundwater quality/demand management strategies and the outcome of systematically planned scientific studies in future.

By adopting efficient use of groundwater for irrigation practices and recycle/reuse of groundwater consume for domestic and industrial purposes, losses can be reduced which help to protect overexploitation will maintain the quality of groundwater for drinking purpose.

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REFERENCES

[1] Acharyya S. K. (2001), 'Arsenic contamination in groundwater affecting major parts of southern West Bengal and parts of western Chhattisgarh: Source and mobilization process', Current Science, Vol. 82, No. 6, 25 March 2002.

[2] Ahsan Syed Md. Fakrul et al. (2008), 'Statistical Modeling of the Groundwater Arsenic Contamination Level in Bangladesh Due to Chemical Elements', Journal of Applied Quantitative Methods, Vol. 3 No. 3.

[3] APHA (1998), 'Standard Methods for the Examination of Water and Wastewater', 20th edition Washington D.C...

[4] BIS (1992), Indian standard specifications for drinking water. IS: 10500,

[5] Brunt R., Vasak L., Griffioen J. (2004), 'Arsenic in groundwater: Probability of occurrence of excessive concentration on global scale', IGRAC.

[6] Feenstra L., Erkel J. van, Vasak L. (2007), 'Arsenic in groundwater: Overview and evaluation of removal methods', IGRAC.

[7] Jakhrani Mushatque Ali, Chaudhray Abdul Jabbar, and Hassan Mukhtar-ul-, Khan Muhammad Malik and Jakhrani Ashfaque Ahmed, Mazari Muhammad Qasim (2009), '*Determination of Arsenic and Other Heavy Metals in Hand Pump and Tube-Well Ground Water of Khairpur, Sindh, Pakistan*', Second International Conference on Environmental and Computer Science.

[8] Liang, Meisheng and Lai, Yongkai (2010), 'Determination of the Arsenic Content in Surface Water by Silver Diethyldithiocarbamate Spectrophotometry', IEEE.

[9] Chakraborty Dipankar et al. (2009), 'Status of groundwater arsenic contamination in the state of West Bengal, India: A 20-year study report' , Mol. Nutr. Food Res. 2009, 53, 542 – 551.

[10] Kumar Sanjay (2011), 'Assessment of Arsenic in Groundwater in Gorakhpur District, Uttar Pradesh, India', M. Tech. Dissertation, Department of Civil Engineering, M. M. M. Engineering College, Gorakhpur (U. P.).