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Assessment of Arsenic in Groundwater and Surface Water Sources of Gorakhpur District in Uttar Pradesh (India)

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Abstract

This study was conducted in 19 blocks and 4 surface water of Gorakhpur district to assess the arsenic content. The study was carried out in the month of February-March, 2021. The result was compared with IS: 10500:2012 and WHO. The increased arsenic content in the water possess serious health issues in humans. The acute health issues being pigmentation on skin and damage to red blood cells. Prolonged exposure leads to liver and kidney cancer. This main focus of this paper is to review the arsenic content and water quality along with the reasons of arsenic contamination in these blocks. It also suggests the prevention methods that are taken and could be taken and also discuss the areas and the gaps that requires further attention in arsenic contamination control in Gorakhpur district. The test was carried out using Spectrophotometer method i.e. Silver Diethyldithiocarbamate (SDDC) method which is a laboratory instrument. This instrument has arsenic detection range from 0.001 to 0.020 ppm. In this method the inorganic arsenic was reduced to arsine by zinc in acid solution in an arsine generator. From this assessment it was found that Gorakhpur district is contaminated by arsenic. Measure step are required to remove this pollution.

Keywords: Arsenic, Groundwater, Surface water, Contamination, Anthropogenic

INTRODUCTION

Arsenic (As) is well-known element found in the Earth's crust. An average of nearly 5 mg/ kg of arsenic is found in soil. Rocks associated with geological and geothermal activities are the significant contributors of arsenic. More than 200 mineral deposits contain arsenic. Human activities like mining, and trade activities using arsenic bearing sulfides are anthropogenic sources of arsenic to the environment.

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Arsenic is widely recongnised now as carcinogen (ATSDR, 2000; National Research Council, 1999; USEPA, 2001).

Growing population and lowering of water table in the country has increased the dependency on ground and surface water to meet the water demand and hence several scientific research were initiated to determine the quality of water and precautionary methods.

Arsenic is a potent carcinogen, causing to skin, bladder, liver, and lung cancers. Arsenic brings epidemiological toxicity. It results in the formation of surplus ROS thereby damaging organisms. Arsenic is also known to reason of cytotoxicity and genotoxicity. It is well-known fact that chronic exposure to arsenic can lead to arsenicosis, including skin lesions, black foot diseases, peripheral vascular disease, and cancers. However, several studies shows that arsenicosis due to elevated level of As [1].

It is supposed that the water quality from deep bore wells and India Mark-II hand pumps would be safe and healthy but the reports about the occurrence of arsenic in such waters have led to deep concern among the scientific circles, the public at large is still not aware about the nature and magnitude of the problem. Hence, groundwater arsenic contaminations poses serious health issues to a large section of communities. Natural occurrences of high arsenic levels were reported in aquifers in groundwater especially unconsolidated sediment aquifers all through the world and have been the reason of major health issues (Smedley and Kinniburgh, 2013; Mozumder, 2019).

After the first case of arsenic groundwater contamination that was surfaced in 1983 in West Bengal, studies have shown that the various states in India such as Uttar Pradesh, Bihar, Assam and Manipur have been exposed to increased arsenic content limit in ground water which is above permissible limit 10 ppm [2].

T.R Chowdhury et al. 1995 shows that in six districts of West Bengal: MaIda, Murshidabad, Bardhhaman, Nadia, 24-Parganas (North) and 24-Parganas (South), arsenic has been reported in groundwater above the maximum permissible limit recommended by WHO. The current provisional arsenic level in drinking-water from WHO is 0.01 mgt (WHO, 1993). This water is generally used by villagers for drinking, cooking and other household purposes [3].

The pollution of groundwater by arsenic has been identified and researched in various parts of the world also. In Argentina, arsenic poisoning was identified in 1913 in drinking groundwater (Bundschuh et al., 2012). Atlantic coastal plain of USA Federal and state MCLs were found to have excess as content in groundwater (Barringer et al., 2010; Drummond and Bolton, 2010; Haque et al., 2008; Mumford et al., 2012; Pearcy et al., 2011).

The South and Southeast Asian Belt is considered among the most arsenic polluted areas which includes India, Bangladesh, Nepal, Vietnam and China (Ravenscroft et al., 2009; McArthur, 2019).

The literature review has indicated that the assessment of arsenic in groundwater and surface water is of paramount importance. Assessment will be able to provide insight into the present status of arsenic in groundwater and surface water that cause the health hazards and the need for suitable removal methodologies towards protecting public health from the adverse effects of arsenic after prolonged use in future [4].

STUDY AREA

Gorakhpur (Latitude 26°13′ N and 27°29′ N and Longitude 83°05′ E and 83°56′ E) is one of the eastern district of Uttar Pradesh in India having geographical area 3,483.8 sq. km.It has an average temperature ranging from 20°C to 31°C and an annual average rainfall between 1016 mm to 1207 mm. Rapti, Aami, Rohini and Ghaghara are the river found in Gorakhpur district (Figure 1)[11].

The mineral products are few. Brick clay is found in abundance and hence bricks are made all over the district. The soil in the district is light sandy or dense clay of yellowish brown color. The sand found in the rivers is medium to coarse grained, greyish white to brownish in color and is suitable for construction. The groundwater study is carried out on the nine blocks of the Gorakhpur district as mentioned below:

1. Bhathat
2. Sahjanwa

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3. Jangal Kauria
4. Uruwa
5. Sardarnagar
6. Brahmpur
7. Chargawa
8. Khorabar
9. Gola

Below mentioned four rivers are covered for surface water analysis:
1. Rohini
2. Ghaghara
3. Aami
4. Rapti.

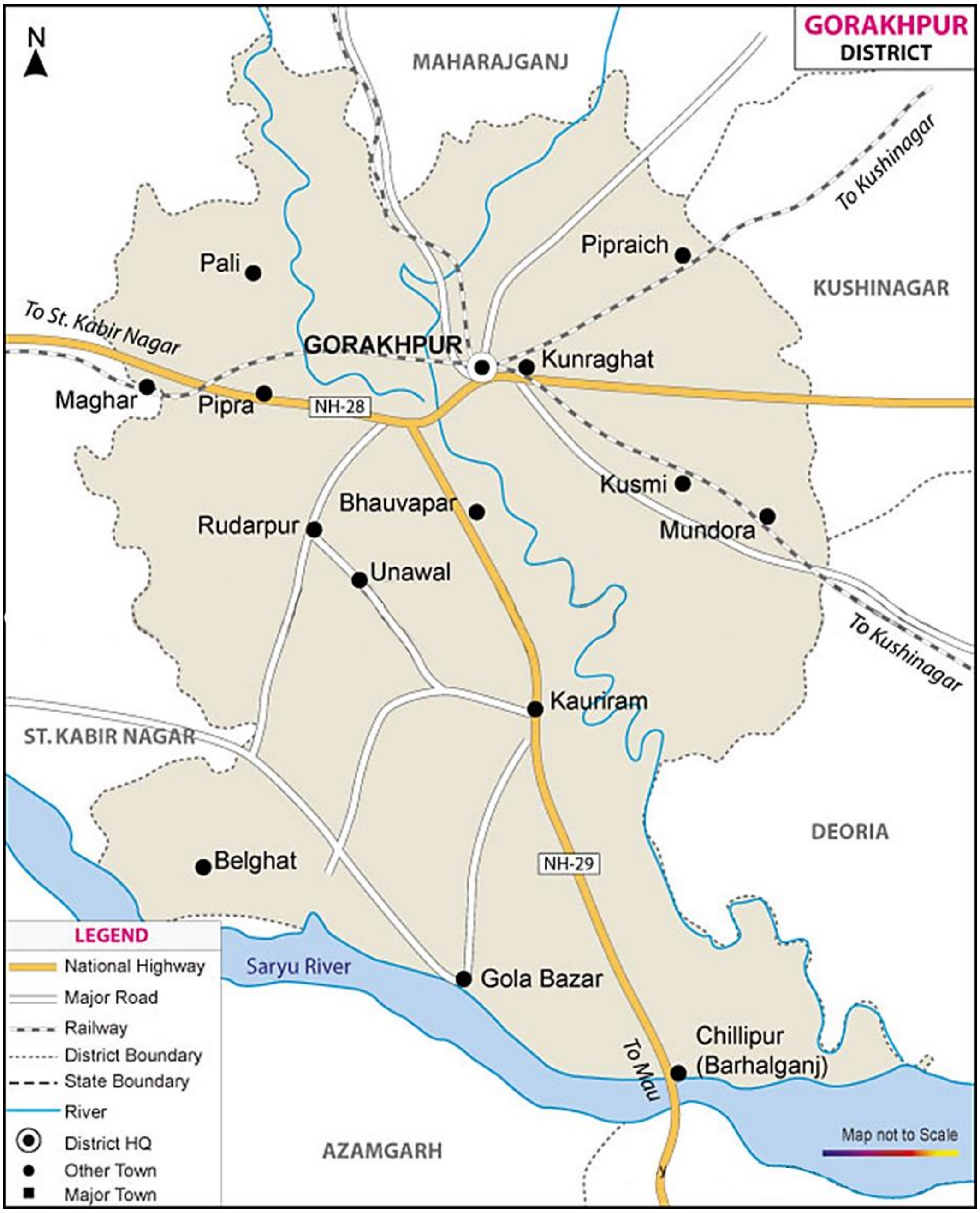


Figure 1. Study Area (https://gorakhpur.nic.in)

MATERIAL AND METHOD

The water samples from 9 blocks and 4 surface rivers were taken. The sample was tested in Jal Nigam Department (U.P) situated in Rapti Nagar Phase 4. The samples were collected in February-March, 2021. The water samples of groundwater was maximum taken from India Mark-2 hand pumps installed by Utter Pradesh Jal Nigam and some from private hand pumps. The Surface water samples were taken from sediment bed and it upstream flow.

The samples were collected in clean polyethylene bottles of 1 litre capacity after few minutes of pumping from hand pump and rinsed twice with a portion of the sample and was brought immediately to the laboratory for further analysis. The result obtained from sample test was compared with IS: 10500:2012 i.e. standard code for drinking water.

Spectrophotometer method is used in this study. This instrument has arsenic detection range from 0.001 to 0.020 ppm. In this test organic compound holding arsenic are decomposed to inorganic arsenic by addition of nitric acid and sulfuric acid and constantly evaporating the solution to Sulphur dioxide fumes [5]. The nitric acid is taken off. The arsenic formed, along with the original inorganic arsenic, is reduced to arsenic with hydrochloric acid, potassium iodide, and tin chloride. The sample is set apart for 15 minutes. Arsenic is reduced to arsine gas, AsH_3, by adding of granular Zinc in a closed system. The arsine is passed by the hydrogen produced through glass wool impregnated with lead acetate and then through an absorbing solution of silver dirthyldithiocarbamate dissolved in pyridine. The time allowed for this reduction is 30 minutes. The arsine reacts with the absorbing solution forming a red-colored complex, absorbance of which measured spectrophotometrically (Figure 2) at 553 nm.

Figure 2. Spectrophotometer (Source: Original)

REACTIONS INVOLVED IN METHOD

The below mentioned equation is involved in the spectrometer method used in the experiment:

$$2KI + H_3AsO_4 + 2HCI = H_3AsO_3 + I_2 + H_2O + 2KCI \quad (1)$$

$$2HCI + H_3AsO_4 + SnCI_2 = H_3AsO_3 + SnCI_4 + H_2O \quad (2)$$

$$H_3AsO_3 + 6H^+ + 6e^- = AsH_3 + 3H_2O \quad (3)$$

$$AsH_3 + 6Ag\,(SDDC) = 6Ag + 3H\ SDDC + As\,(SDDC)_3 \quad (4)$$

RESULTS AND DISCUSSIONS

The samples of ground water and surface water tested for Gorakhpur district with block-wise scenario showing acceptable (<0.001 ppm to <0.010 ppm) and rejection (>0.020 ppm) concentration are shown in Tables 1–3. The test results shows that samples in Bhathat, Khorabar, Chargawa, Sardarnagar, Gola are found within the range where in Sahjanwa, 16.67% of samples was above the limit and in Brahmpur, Uruwa and Jangle Kauriya 33.33% of samples was found above the norms.

Ground Water Analysis

Table 1. Detail of the arsenic content in the water in the blocks under study.

Block Name	No of samples	Arseni Limits		Maximum value observed (ppm)
		<0.001 ppm to <0.010 ppm	*>0.020 ppm*	
Bhathat	6	6	0	0.001
Sahjanwa	6	5	1	>0.020
Khorabar	6	6	0	0.005
Chargawa	6	6	0	0 002
Jangal Kauriya	6	4	2	>0.020
Gola	6	6	0	0.003
Sardarnagar	6	6	0	0.006
Uruwa	6	4	2	>0.020
Brahmpur	6	4	2	>0.020
Total	54	47	7	
Percentage	100	87.03	12.97	

The evaluation of arsenic concentration in 54 groundwater and 12 surface water samples of Gorakhpur district, Uttar Pradesh, India has provided useful insight into the extent of arsenic toxicity in research area. Maximum sample was taken from India Mark-2 hand pumps. With this view, a detailed investigation about local sources of arsenic and mechanisms of arsenic release is required [7].

About 87.03% of groundwater samples were arsenic concentration in the range of <0.001 ppm to <0.010 ppm and 12.97% of samples were found above 0.020 ppm.

Table 2. Arsenic Concentration range in terms of Percentage

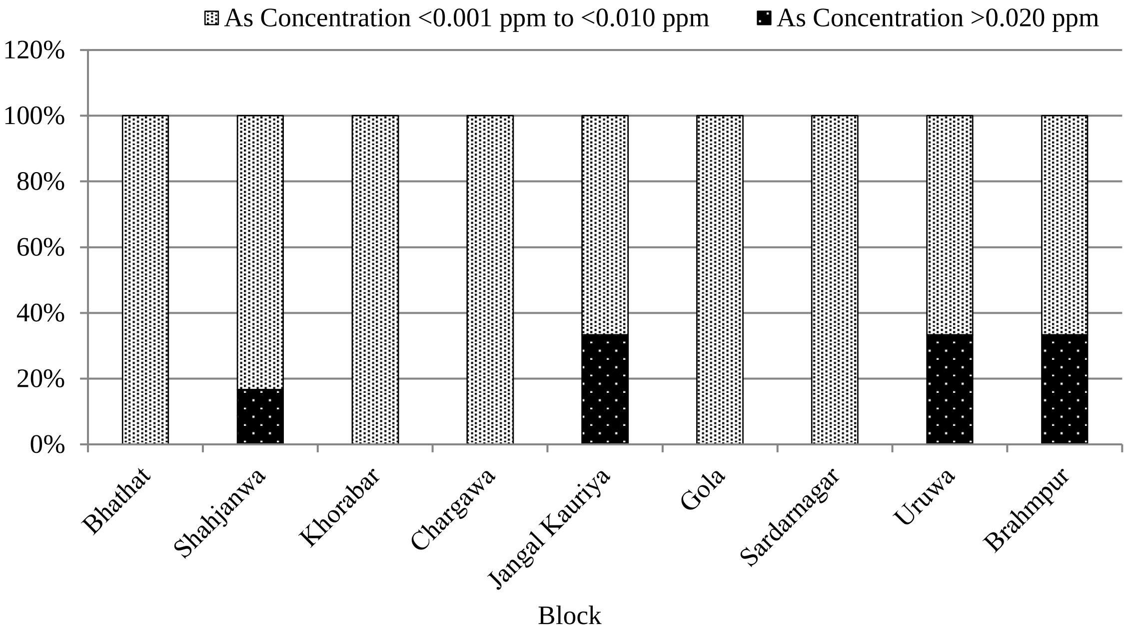
Block Name	<0.001 ppm to <0.010 ppm	>0.020 ppm
Bhathat	100	0
Shahjanwa	83.33	16.67
Khorabar	100	0
Chargawa	100	0
Jangal Kauriya	66.67	33.33
Gola	100	0
Sardarnagar	100	0
Uruwa	66.67	33.33

Brahmpur	66.67	33.33

Table 2 at glance shows that the installation of arsenic removal units is compulsorily required at such hand pumps where arsenic is more than the permissible limit.

This study shows that high arsenic concentration was observed in the groundwater with the depth more than 30 meters. This lead to a conjecture before the consumer whether to have arsenic free contaminated water from shallow depth or contamination free high arsenic water from deep aquifer [6].

The arsenic content in ground water of the blocks of Gorakhpur district can be summarized as a graphical representation as shown in Graph 1 for better understanding.



Graph 1: Arsenic concentration in ppm

Surface Water Analysis

The surface water was also covered in the study area. 4 river, Aami, Rapti, Rohini, Ghaghara, water samples were collected to check the arsenic contamination. Total 12 samples were collected. The samples location was from surface flow and sediment bed [8]

Table 3. Arsenic Concentration in surface water samples

S. N.	Source	No of Sample	Location	Maximum Arsenic observed (ppm)
1	Aami River	2	Bed	0.002
			Surface	0.001
2	Rapti River	2	Surface	0.002
			Bed	>0.020
3	Ghaghara River	4	Surface	0
			Bed	0
4	Rohini River	4	Surface	0.003
			Bed	>0.020

From the assessment of arsenic in surface water it was found that only Ghaghara River was found with 0% arsenic. Where in Aami river the arsenic concentration was found within limit (<0.001 ppm to <0.010 ppm). And the alarming situation was found in sediment bed samples of Rohini and Rapti river samples. It was found above the permissible limit i.e. >0.020 ppm.

The disposal of ashes in the river near funeral places is one among the reason of increasing arsenic content in the river. Another reason to considered is the presence of anthropogenic sources of arsenic and further investigations may be required.

Reason and Theory of Contamination

In addition to above findings, it is believed that contamination of in groundwater is generally due to long uses of its compound and pesticides. Arsenic component are generally found as the trace component in many rocks and sediments. And it is supposed that due to overexploitation of groundwater and lowering of the water table are main cause of release of arsenic from deep strata and causing contamination in groundwater of various district Gorakhpur.

In surface water the arsenic contamination are also generally due to various chemical discharge from industries rubber, pesticides, textile etc. The arsenic contamination in surface water and groundwater are both natural and industrial [10].

Natural process can be understood by well-known two theories i.e. oxidation and oxyhyroxide theory.

Oxidation Theory

In oxidation theory, arsenic is released from the sulfide minerals (arseno-pyrite) in the shallow aquifer due to oxidation process. The discharge of groundwater on large scale and and lowering of water table are cause of arsenic in groundwater [11]. The overexploitation of ground water lead to the rapid diffusion of oxygen within the pore space of sediments and also increase the dissolved oxygen content in upper part of the groundwater.

Newly admitted oxygen oxidizes the arseno-pyrite and forms new hydrated iron arsenate compound known as pitticite in prescence of water [12]. This newly formed compound are very soft and water-soluble compound. This is so soft that light pressure of hand pump break the pitticite layer into fine particles and get soluble in water. It percolate from subsoil into watertable. This is reason, when hand pumps are used it come with the water.

Oxyhydroxide Theory

Whereas in oxyhydroxide theory, the arsenic contamination are caused due to the desorption of arsenic from ferric hydroxide minerals [9]. This process occurs in reducing condition of water table. The ferric hydroxide is found as coatings in the aquifer sediments.

In both of this theory, oxidation process is known to be main causes of arsenic contamination in groundwater.

RECOMMENDATIONS AND CONCLUSIONS

It is important to define arsenic at low levels in the environment because of the chronic toxicity of arsenic compounds. It is even more important to differentiate between the species of arsenic because they show widespread differences in toxicity, arsenic being the most harmful.

From this assessment it is concluded that arsenic contamination has become major problem that is being faced by Public health engineering department, in the both urban and rural area. The assessment of arsenic pollution in groundwater and surface water in Gorakhpur district has given following recommendation and conclusions:

1. In this study 54 samples were taken from groundwater in which 87.03% of them where within limit i.e. <0.010 ppm and 12.97% where above the limit. The work should be carried out to

remove arsenic totally because drinking water with low level of arsenic over long time causes diabetes and risk of cancers of the bladders, lungs, liver, and other organs. It also contributes to the cardiovascular and respiratory diseases, lowered intelligence in kids, and skin problems such as lesions, discoloration and development of corns.

2. In this assessment 12 surface water samples was also checked for arsenic contamination in which 2 samples was above the norms i.e. >0.010 ppm. Arsenic was not found at the places were flow of rivers was good due to self-purification of rivers
3. The overexploitation of groundwater should be stop by adopting various water conservation system.
4. The discharge of chemical from various industries like rubber, textile, pesticides etc. must be stopped to save surface water from getting arsenic contaminated.
5. The uses of hand pump and surface water where arsenic contamination is identified should be avoiding until safety measures are not taken.
6. The arsenic contamination in surface water indicates the possibility of flowing arsenic bearing sediments and some anthropogenic pollution.
7. The hand pumps should be installed deeper and precaution must be taken against cross contamination.
8. “Arsenic Support Cell” equipped with test facilities and trained staff should be established at district level to deal with arsenic related problem.

From the assessment it is concluded that groundwater and surface water of Gorakhpur district is affected by arsenic due to which high safety measures and investigation is needed. Both area should be marked where it arsenic free or contaminated. And the hand pump where arsenic contamination is found proper arsenic removal units are required.

By efficient uses of groundwater and surface water mainly for irrigation purpose and by recycling of groundwater, the load on groundwater will get minimized and water table will maintained and by working on Zero discharge method Surface water arsenic contamination will get reduced.

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