Research Article

Spatial Relationship of Various Parameters in Drinking Water in Siwan town of Bihar (India) with Special Emphasis on Arsenic Contamination in Groundwater

Dr Subhash Prasad Singh*

Department of Chemistry, A N College, Patna-800 013

Abstract

Arsenic contamination in natural water depends on the local geology, hydrology and geochemical characteristics of the aquifer materials. Furthermore, the geochemical characteristics of the aquifer material and their interactions with the aqueous media play an important role in controlling retention and/or mobility of arsenic within the subsurface environment. The presence of arsenic (As) in water and its effect on human health through both drinking and agricultural practices is of serious concern worldwide. In India, arsenic rich groundwater above the permissible limit of 10 µg/L mostly occurs in the Bengal Delta Plain, covering the state of West Bengal, the adjoining country of Bangladesh and extending to Jharkhand, Chhattisgarh, Bihar, Uttar Pradesh, in the flood plain of the river Ganga, Assam and Manipur in the flood plain of the river Brahmaputra and Imphal rivers and other Northeastern states of India and the neighboring country of Nepal. With every new survey, more Arsenic affected villages and people suffering from Arsenic related diseases are being reported, and the issues are getting complicated by a number of unknown factors. This article reports the inclusion of Siwan district as the 13th district in Bihar state in India being arsenic prone and conceptualizes by reviewing the arsenic sources, major occurrences, and process of contamination through an integrated approach. Siwan (Bihar) falls in fluvial plains. These fluvial plains represent Holocene aquifers of recent alluvial sediments and have the routes originated from the Himalayan region.

The deeper aquifers, which seem to be risk free from future threat of contamination from the overlain aquifer, will certainly be at stake if thrust of water withdrawal is put into. It is advisable not to put pressure on deep boring for safe and sustainable future. Surface waters are free from arsenic contamination. The usages of surface water sources with minor treatment through organized piped water supply system need to be encouraged. Thus making society responsible and knowledgeable can solve many problems associated with the water scarcity issues in the arsenic affected areas along with capacity building.

***Correspondence**

Dr Subhash Prasad Singh,
Department of Chemistry,
A N College, Patna – 800013
Email: singhdrsp@rediffmail.com

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Introduction

Waterless life is impossible to exist on Earth. It is the dispersion medium for all biochemical reactions of the living process and takes part in many of these reactions. Therefore, when we consume water, it does not simply quench the thirst but performs several other vital functions inside the body. The qualities of drinking water are thus reflected in the health vitality of the people. Water is universal solvent. It dissolves almost all things whatever comes in contact

with it. The aquatic pollutants bring out alterations in physico-chemical characteristics of water as an immediate effect. In due course of time these pollutants accumulate in water bodies and alter the ecological conditions gradually. Hazardous chemicals from careless disposal of domestic, municipal waste, industrial effluents, and use of pesticides enter into the aquatic media and cause a chain of undesirable effects on water quality and aquatic organism.
The occurrence of Arsenic in ground water was first reported in 1980 in West Bengal (India) and in 2002 in Semria Ojha Patti village and Pandeytola in Bhojpur district of Bihar. By now it has been reported that Bihar is being surrounded by West Bengal, Uttar Pradesh, Jharkhand, Assam, Bangladesh, Nepal and China. **Figure 1** shows Arsenic affected stretches in Ganga Plains [1] in India with reference to Ganga-Meghna-Brahmaputra Plains [4].

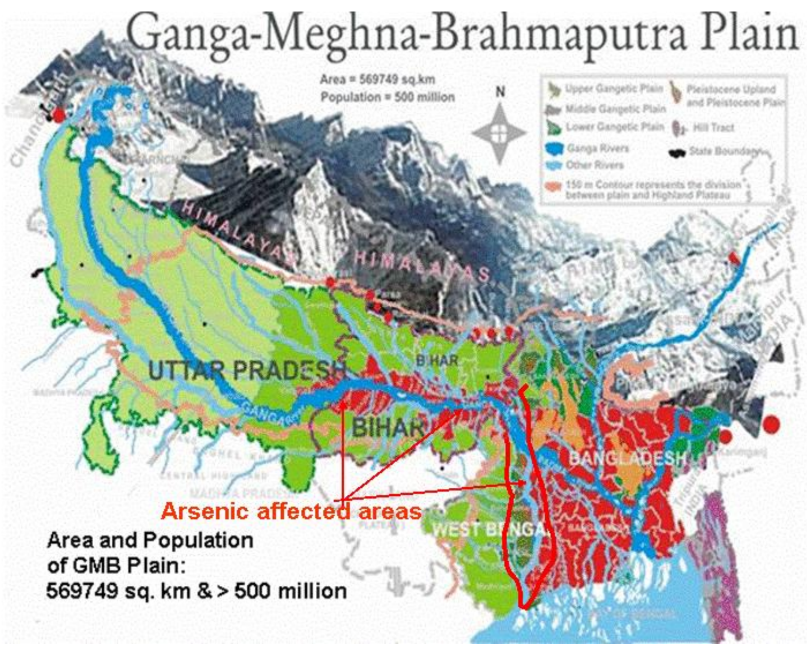

Figure 1 Arsenic affected stretches in Ganga Plains in India with reference to Ganga-Meghna-Brahmaputra Plains.

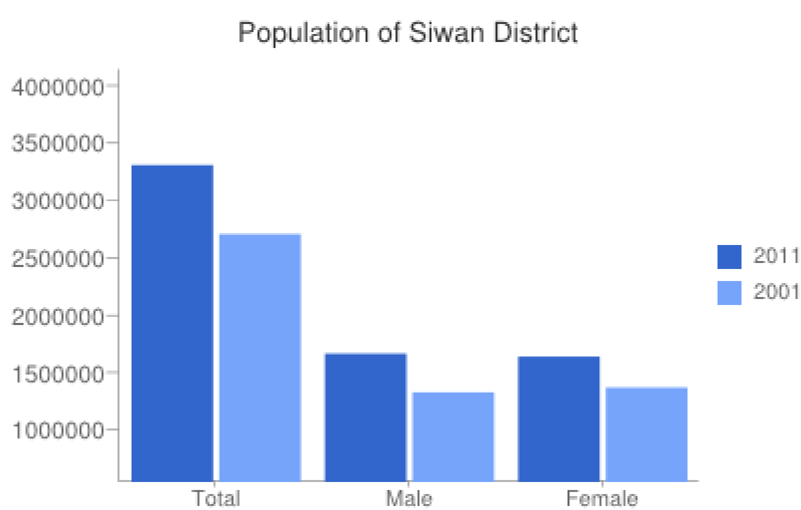

Figure 2 Population of Siwan District

Wells and tube wells are the drinking water sources for residents of Siwan (Bihar) district headquarter. The name Siwan is derived from “Shiva Bandh”, a Bandh Raja who ruled this area once upon a time. His successor reigned till Mugal Emperor Babar’s advent. The latitude of Siwan is 26,2167 ($26^0$13’0.120”N) whereas its longitude is 84,3667 ($84^0$22’0.120E) and its altitude is 64m. The location of the town is on the eastern bank of river *Daha*. There are 38 wards in Siwan Nagar Parishad consisting of 182,311people as per Census 2011 data whereas the total population of the district is 3318176 (**Figure 2**). Male: female sex ratio in Siwan town is 912 whereas the average male and female literacy of the town is 89.48% and 74.21% respectively.

Geo-morphology of the Soil

Structurally Siwan district (**Figure 3**) forms a part of the alluvium of the broader Indo-Gangatic Plain. The geological formation of the tract is of recent (Holocene) period. The contribution of the Himalayan Rivers to the formation of the tract is significant. It is estimated that the district covers the deposits of alluvium more than 5000 feet depth. Geo-morphologically it forms the part of the Gandak cone which is the outcome of the discharge and slit charge of the Himalayan Rivers to the plain during the phase of deposition. Siwan district falls in the area, which occupies an intermediary position between the Bhanger plain of Uttar Pradesh and Khadar plain of West Bengal.

Figure 3 Map of Siwan

Bhanger is the older alluvium containing heavier soil with greater clay proportion, while Khader is the newer alluvial deposit by river floods. Both types of soils are found in the district, but Khader is limited to the vicinity of the rivers where it is periodically renewed by fresh deposits, especially in “Diara” areas.

Materials and Methods:

Upon continuous health-related complaints from locals especially in regard to stomach disorder, the investigator decided to initiate a water quality assessment study in Siwan Nagar Parishad. Initially ward wise primary survey was conducted in Siwan town which included demographic & physiographic condition, year of sinking of tube well, depth of tube wells / wells, number of users and health status of people, etc. A total of 38 monitoring stations (i.e., 2 open dug wells and 36 tube wells) were selected and sampled in order to understand the various parameters in the unconfined aquifer.

The detailed physico-chemical & biological analysis of water was conducted for various sources in all the wards in urban area of Siwan. Parameters such as pH, temperature, dissolved oxygen, total dissolved solid, residual chlorine, turbidity, chloride, nitrate, fluoride, sulphate, phosphorous, iron, hardness, ammonia, sodium, potassium, arsenic, and coliform bacteria have been analyzed.

The analysis was followed as per the Indian Standard and as per the standard procedure recommended by APHA [2]. Within the scope of field sampling campaign, two sets of samples were collected from each sampling station (i.e., 1000 mL for standard anion and cation analysis and 50 mL for trace element and heavy metal analysis).

All samples were filtered and stored in good quality screw capped polyethylene bottles until analyzed for the physico-chemical parameters. Some of the parameters such as pH, temperature, electrical conductivity, dissolved oxygen, turbidity, total dissolved solid, etc. were measured on the spot itself whereas some were examined and re-examined in the laboratory. All 50 mL samples collected for heavy metal analysis were then acidified to achieve pH value of less than 2.

The equipments such as pH meter, Conductivity meter, Nephlometer, Dissolved Oxygen meter, Flame photometer, Spectrophotometer 167, and Atomic Absorption Spectrophotometer (AAS) used in the analysis are of Systronic make. Mostly AR grade chemicals of Merck, Himedia or Qualigens make were used for analytical purposes. Necessary solution was made in double distilled water only. The cation analysis was performed with ICP-MS and Spectrophotometer. Arsenic measurement was carried by AAS in National Metallurgical Laboratory, Jamshedpur, Jharkhand, India.

Concentration of Sodium and Potassium was measured by Flame photometer. Chloride and bicarbonate ions were analyzed with volumetric methods; nitrate measurements were done by photometric methods and sulfate analysis was conducted with gravimetric methods.

The average value of a particular parameter during the study period has been taken into consideration as a representative value for the purpose of studying variation in the water quality.

Results and Discussions

The experimental findings are summarized in **Table 1**. To look into the distribution trend and pattern of various parameters in drinking water, data obtained were exposed to several statistical treatments.

Table1 Average value of parameters of drinking water of Siwan Nagar Parishad

S.N.	Source & depth of tube well	pH	Temp	Dissolved Oxygen	Residual Chlorine	Turbidity	Chloride	Nitrate	Flouride	Sulphate	Phosp-horous	Iron	Hardness	Ammonia	Sodium	Potassium	Arsenic	Total	Coliform
	(TW) & open dug Well	**6.5-8.5**	**(°C)**	**5mg/lit (min)**	**0.2mg/lit**	**Max 5-10 NTU**	**250-1000 mg/lit**	**45-100 mg/lit**	**0.6-1.5 mg/lit**	**200-400 mg/lit**		**0.3-1.0 mg/lit**	**300-600 mg/lit**	**mg/lit**	**mg/lit**	**mg/lit**	**WHO [12] std 10ppb Indian std 50ppb**	**Dissolved Solid 500-2000 mg/lit**	**Bacteria**
1	TW-170'	**9.1**	25°C	1	negligible	3.3	**35.45**	5	0.6	225	0.1	1	**248**	0.9	30.55	0.74	10	509	nil
2	TW-140'	**9.1**	25°C	1	negligible	3.9	**35.45**	7	0.6	237	0.1	1	**248**	0.9	31.01	0.78	10	507	nil
3	TW-170'	**9.1**	25°C	1	negligible	3.3	**35.45**	5	0.6	227	0.1	1	**248**	0.9	30.84	0.81	10	505	nil
4	TW-170'	**9.1**	25°C	1	negligible	3.5	**35.45**	5	0.6	225	0.1	1	**248**	0.9	30.67	0.79	10	506	nil
5	TW-140'	8.15	26°C	3.4	negligible	4.1	**145.3**	6	0.6	240	0.2	1	**248**	0.9	35.15	0.91	10	525	nil
6	TW- 168'	**9.5**	25°C	1.2	negligible	3.8	**116.99**	5	0.6	227	0.1	1	500	1	46.75	1.99	10	520	nil
7	TW-35	8.2	25°C	1.8	negligible	**15.01**	329.69	9	0.7	**455**	0.9	1	340	2.9	70.36	109.29	**100**	**2180**	**present**
8	TW-35	8.2	25°C	1.8	negligible	**10.02**	312.4	9	0.7	**448**	0.7	1	340	2.9	70.34	109.23	**100**	**2156**	**present**
9	TW-20'	7.1	25°C	0.5	0.2	**30.01**	425.4	9	0.8	**460**	0.5	0.3	**680**	0.9	71.05	89.76	10	**2166**	**present**
10	TW-35'	7.1	25°C	0.45	0.2	**14.01**	400	9	0.7	315	0.1	0.3	**650**	0.9	69.99	75.94	10	1508	**present**
11	Open Well (very old)-60'	6.8	25°C	0.5	negligible	9.4	**194.98**	9	0.7	380	0.1	0.3	380	3	78.06	61.78	10	1623	**present**
12	TW-35'	**9.1**	25°C	1.5	negligible	9.3	496.3	100	0.7	**417**	0.1	0.3	**820**	1	70.39	53.33	10	1099	**present**
13	TW-50'	8.15	25°C	2.5	negligible	9.2	283.6	100	0.4	**480**	0.1	0.9	580	0.5	58.05	18.21	10	**2202**	nil
14	TW-200'	**9.1**	25°C	1.01	negligible	3	**17.73**	5	0.6	300	0.1	0.3	**200**	0.5	17.78	9.07	10	700	nil
15	TW- 80'	8.1	28°C	0.1	negligible	6.02	**35.45**	6	0.7	319	0.1	1	**272**	1	90.19	17.82	20	1011	nil
16	TW-36'	8.5	25°C	0.4	negligible	**12.11**	**35,45**	9	0.7	**411**	0.1	0.9	320	1	69.11	16.79	10	1550	**present**
17	TW-160'	7.15	25°C	3.4	negligible	4.2	**17.73**	5	1.5	260	0.1	0.3	**280**	1	18.91	7.89	*50*	1789	nil
18	TW-150'	7.15	25°C	3.4	0.2	4.01	**202.07**	100	0.6	290	0.3	0.3	552	1	19.79	10.76	10	1200	nil

19	TW-200' (Stored water)	**9.1**	25°C	5	negligible	3.3	**106.35**	12	0.6	240	0.1	**0.2**	360	0.5	12.12	7.9	10	1165	nil
20	TW-200' (Stored water)	**9.1**	25°C	5	negligible	3.3	**106.35**	12	0.6	240	0.1	**0.2**	360	0.5	12.15	7.89	10	1169	nil
21	TW-200' {Stored water)	**9.1**	25°C	1.3	negligible	3.3	**106.35**	10	0.6	240	0.1	**0.2**	360	0.5	12.16	7.86	10	1160	nil
22	TW-200' (Stored water)	**9.1**	25°C	1	negligible	3.3	**246-01**	39	0.6	240	0.1	**0.2**	360	0.5	11.98	7.88	10	1170	**present**
23	Shallow Well	**10**	25°C	3.4	1	8.9	**106.35**	8	0.9	**430**	0.1	**0.2**	400	0.6	42.13	48.8	**100**	**2190**	**present**
24	Supply Water TW-200'	7.1	25°C	1	negligible	8.1	**35.45**	9	0.6	310	0.1	0.3	**260**	0.5	13.98	5.97	**110**	1801	**present**
25	Supply Water TW-200'	7.1	25°C	1	negligible	8.12	**35.45**	9	0.6	315	0.1	0.3	**240**	0.9	14.18	5.8	**100**	1769	**present**
26	TW-200'	8.5	25°C	1	0.2	3	**39.1**	9	0.6	316	0.1	0.3	300	0.6	14.08	5.91	20	1790	nil
27	TW-60'	8.5	25°C	1.2	negligible	8	**28.36**	9	0.7	375	0.4	0.3	304	0.9	45.1	36.21	10	1561	nil
28	TW-45'	8.5	25°C	1.5	0.1	8.1	**194.98**	100	0.7	**406**	0.4	0.3	**740**	0.9	49.55	29.65	25	1581	**present**
29	TW-150'	**9**	25°C	1	negligible	6.15	**43.18**	45	0.6	250	0.1	0.3	320	0.6	18.15	11.12	10	909	nil
30	TW-50'	**9.1**	25°C	2	0.2	7.2	**177.25**	45	0.7	**404**	0.1	0.3	460	1	41.11	16.18	10	1499	nil
31	TW-45'	**9.51**	25°C	0.5	negligible	**12.01**	258.79	45	0.7	**417**	0.1	1	480	1	41.32	16.65	**100**	1909	**present**
32	TW-45'	**9.51**	25°C	0.5	negligible	**11.89**	258.79	45	0.7	**415**	0.1	1	480	1	41	17.15	**150**	1908	**present**
33	TW-45'	8.1	24°C	1.5	0.1	10	**159.53**	9	0.5	**408**	0.1	0.8	520	1	49.32	26.65	10	1898	nil
34	TW-150'	**9.1**	24°C	1.3	negligible	6.3	**17.72**	5	0.6	399	0.1	0.3	**60**	0.5	81.8	76.65	10	518	nil
35	TW-45' (Old)	7.15	24°C	1.5	0.5	7.99	**212.7**	**116**	0.5	398	0.1	0.3	**640**	2	41.98	46.01	**100**	1788	nil
36	TW-200' (New)	7.1	24°C	1	negligible	3	**35.45**	5	0.5	219	0.1	0.3	300	0.5	106.11	16.01	10	504	nil
37	TW-45'	7.2	24°C	1.6	0.1	8.2	**170.16**	100	0.7	325	0.1	**1.3**	**760**	0.5	59.67	66.77	10	1660	nil
38	TW-38'	8.5	24°C	0.6	0.1	8.6	**70.9**	45	0.8	367	0.1	0.3	400	1	89.67	67.54	10	1719	nil

The chemical and bio-chemical interactions between water and the geological materials through which it flows cause varieties of dissolved inorganic chemical constituents in various concentrations in ground water. The surface water bodies and even atmosphere contribute to it. The variation in various parameters of drinking water samples studied in urban area of Siwan is reported as shown in **Figure 4**.

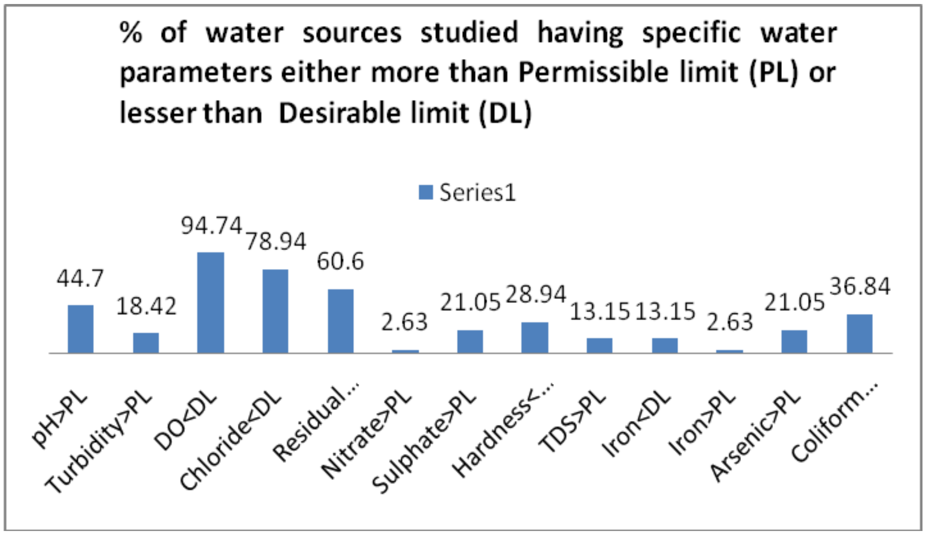

Figure 4 % of different parameters in water sample studied

Most of the water samples studied in Siwan town contains 10ppb arsenic whereas Sample 15, 26 and 28 contain 20ppb. Sample 17 contains 50ppb but sample 7,8, 23, 24, 25, 31, 32 and 35 contain ≥100ppb. **Figure 5** is the graphical representation of arsenic concentration beyond the permissible limit in the samples specified.

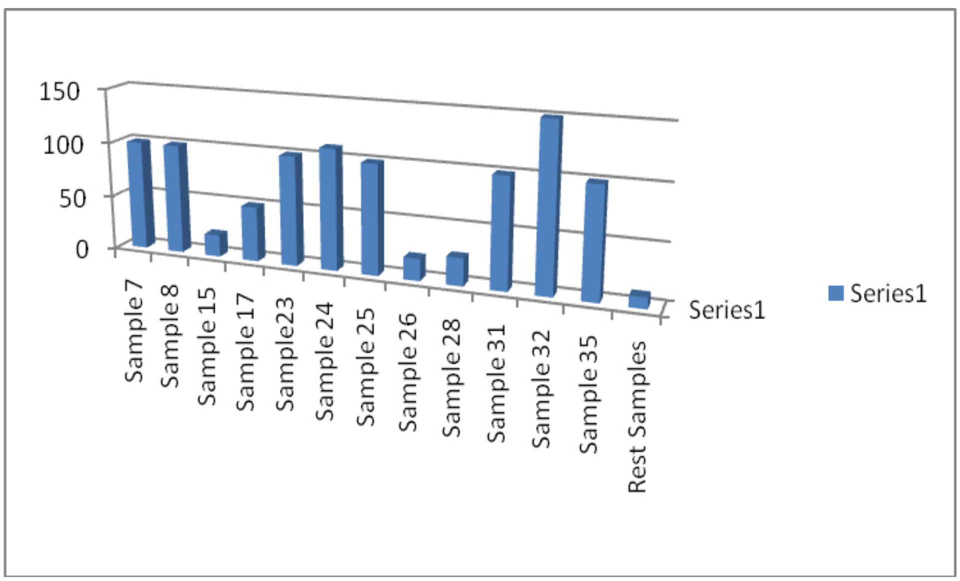

Figure 5 Graphical representation of Arsenic concentration in different water samples

The occurrence of Arsenic in ground water is mainly in the depth range of 20-60feet. Sample collected at Public Health Engineering Department's water supply source contains 10ppb arsenic only whereas sample 24 & 25 of the same supply source contain ≥100ppb arsenic. It is indicative of broken water supply pipes due to which impurities present in upper soil rich in arsenic is dissolved in supply water. It is also observed that the contamination of arsenic in ground water occurs at patches in the town. Dhobi Ghat, Puranakila Pokhra, DAV More, Anandnagar, Shuklatoli, and General Hospital area of Siwan are arsenic prone area. Since deeper aquifer is safe and free from arsenic contamination in Siwan, a shallow bored tube well was replaced by authority in the General Hospital premises upon suggestion of the researcher undertaken the project for the benefit of the masses. An open well near DAV More of Siwan town is also found to have arsenic contaminated water which was suggested to discard for drinking and cooking purposes.

Researchers in Bihar have taken keen interest in Gangetic belt [1, 5], so far and reported earlier that this zone being newer alluvial area is arsenic prone area. In addition the present study reports that Siwan, the region near to Ghaghra river is arsenic prone. It further identifies Siwan as an additional district (i.e., 13th district) in Bihar having Arsenic contaminated ground water by the time of submission of project report to the UGC in 2008. **Figure 6** reflects the availability of Arsenic in ground water in various districts of Bihar starting with Bhojpur, Patna, Begusarai, Khagaria, Samastipur, Bhagalpur, Saran, Munger, Katihar, Buxar, Vaishali, Darbhanga and Siwan.

Figure 6 Map of Bihar, India

No clinical effect of Arsenicosis has been observed in Siwan town. However, a lady having dark patches on her legs was examined for arsenicosis with her nails and hair but it was simply a dermatological case.

A conventional descriptive statistical summary of the results of water quality parameters based on normal distribution has been reflected in **Table-2**. Correlation among the studied parameters is presented in **Table-3**.

Table 2 Descriptive statistics for water quality parameters

Mean	8.396842	24.94737	1.548947	0.076316	7.551316	146.4239	28.42105	0.663158	332.3684	0.171053	0.560526	401.5263	0.989474	44.90921
Median	8.5	25	1.105	0	7.595	106.35	9	0.6	317.5	0.1	0.3	360	0.9	41.65
Mode	9.1	25	1	0	3.3	35.45	9	0.6	240	0.1	0.3	248	1	#N/A
Standard dev.	0.901626	0.655429	1.189726	0.185172	5.04909	127.6811	35.28696	0.166719	83.82815	0.179952	0.361333	173.9397	0.642962	26.20387
Variance	0.81293	0.429587	1.415448	0.034289	25.49331	16302.46	1245.169	0.027795	7027.158	0.032383	0.130562	30255.01	0.4134	686.6428
Skewness	-0.38565	2.483922	1.614	3.871521	2.501054	1.032406	1.486896	3.506477	0.083718	2.868719	0.530585	0.756247	2.334344	0.45538
Kurtosis	-1.12556	12.74242	2.227287	17.35003	9.695762	0.394389	0.750806	17.37528	-1.48102	8.226626	-1.56889	0.050633	5.050009	-0.74641
First quartile	7.425	25	1	0	3.575	35.45	6.25	0.6	240	0.1	0.3	274	0.525	19.13
Second quartile	8.5	25	1.105	0	7.595	106.35	9	0.6	317.5	0.1	0.3	360	0.9	41.65
Third Quartile	9.1	25	1.75	0.1	9.275	210.0425	45	0.7	407.5	0.1	1	495	1	69.77

Table 3 Pearson's correlation

	pH	turbidity	chloride	nitrate	sulphate	Phosphorous	Hardness	Ammonia	Sodium	Potassium	Arsenic	Total dissolved solid
pH	1	**-0.29544**	-0.11485	-0.13393	-0.08857	-0.16766	-0.21077	-0.28417	-0.25978	-0.28087	-0.03182	-0.30246
turbidity		1	**0.668432**	0.063379	**0.707059**	**0.466342**	**0.459732**	**0.299824**	**0.436263**	**0.652164**	0.261374	**0.625101**
chloride			1	**0.409314**	**0.614953**	**0.409295**	**0.74951**	**0.368727**	**0.333309**	0.60936	0.232097	**0.504329**
nitrate				1	**0.333631**	-0.0308	**0.730315**	-0.01207	0.047129	0.096442	0.045088	0.24721
sulphate					1	**0.4223**	**0.4216**	**0.405793**	**0.475954**	**0.652302**	**0.392576**	**0.756464**
Phosphorous						1	0.096949	**0.602297**	0.238006	**0.627078**	0.258028	**0.376526**
Hardness							1	0.062642	0.220175	**0.319427**	-0.00951	**0.415248**
Ammonia								1	**0.35282**	**0.576996**	**0.352542**	**0.343468**
Sodium									1	**0.640926**	-0.08864	0.1138
Potassium										1	0.194389	**0.4877**
Arsenic											1	**0.554277**
Total dissolved solid												1

The Pearson's correlation coefficient is a measure of linear association among different variables. Correlation coefficient ranges between -1 (a perfect negative relationship) and +1 (a perfect positive relationship). A value of zero indicates no linear relationship. It is also observed that some of the water quality parameters are negatively correlated and hence is significant at the 0.05 level.

A result of -1 means that there is a perfect negative correlation between the two values at all, while a result of 1 means that there is a perfect positive correlation between the two variables. A result of 0 means that there is no linear relationship between the two variables.

High concentrations of arsenic tend to occur in sulphide minerals and metal oxides, especially iron oxides. Several studies suggest that the As-rich groundwater is mostly restricted to the alluvial aquifers of the Ganges delta comprising sediments carried from the sulphide-rich mineralized areas of Bihar and elsewhere surrounding the basin of deposition [6, 3].

One of the main conclusions from recent research studies has been that desorption or dissolution of arsenic from iron oxides is an important or even dominant control on the regional distributions of arsenic in water [10]. The onset of reducing conditions in aquifers can lead to a series of changes in the water and sediment chemistry as well as in the structure of iron oxides.

Most experts [7, 8, 9] agree that the source of such high arsenic, anomaly in groundwater is geological rather than from pesticide or other artificial sources. It is postulated that arsenic bearing sulphide minerals, the commonest of which in nature is arsenopyrite and/or their alternation products, had been transported in the geologic past possibly from those occurring along the foothills of the Himalayas and deposited with the alluvium in the Ganges–Brahmaputra basin [4].

Conclusion

This article reports the inclusion of Siwan district as the 13th district in Bihar state in India being arsenic prone. Detailed studies on the local and regional geology, hydrogeology and tectonics of the area has revealed that high arsenic values in surface and subsurface waters of Siwan are mainly related to the naturally occurring arsenic containing strata within the lower geological units of the plain. Thus the following conclusions were drawn from the study;

i. Findings of Arsenic were conveyed and possible precautions were suggested to the inhabitants through print/electronic media, district administration and through interpersonal communication campaign adopting problem specific communication strategies as and when required as a part of mitigation measures.

ii. A part of the arsenic contamination in the area specified is possibly mainly geological. The immediate source material for groundwater is likely to be ferric arsenate (with or without ferric arsenite) derived from an alternation product of the mineral arsenopyrite that was geologically transported to the Bengal delta.

iii. Contamination in groundwater takes place by chemical and biological processes. The plausible chemical process is hydrolysis of arsenate and the biological processes with the dump of waste near water sources.

iv. There is no clinical effect of arsenicosis observed on animals even after consumption of arsenic contaminated water for long in the area. In animal models, low concentrations of arsenic exposures alone do not cause cancers [11]. However, the synergistic effects of arsenic and other carcinogens (such as smoking and ultraviolet irradiation) are suggested to enhance the tumorigenicity [13].

v. Deeper aquifer is safe and free from arsenic contamination in Siwan. However, the deeper aquifers, which seem to be risk free from future threat of contamination from the overlain aquifer, will certainly be at stake if thrust of water withdrawal is put into. It is advisable not to put pressure on deep boring for safe and sustainable future. Surface waters are free from arsenic contamination. The usages of surface water sources with minor treatment through organized piped water supply system need to be encouraged.

vi. It has been reported that the arsenic contaminated water gets oxidized in contact with atmospheric oxygen in open well but excess oxygen during withdrawal of groundwater from tube wells appears to be responsible for hydrolysis.

vii. Arsenic issues are getting complicated by a number of unknown factors. Therefore, an integrated research is a must to understand sources, release mechanisms, mobilization of Arsenic in aquifers and the chemistry of arsenic and high arsenic anomaly in groundwater.

viii. The need for research on hydro - geological aspects of arsenic contaminated aquifers is stressed to capture the peculiarities of Bihar, which is generally ignored. Reporting the presence of Arsenic beyond permissible limit through print and electronic media without having any adverse effect on consumers should be restricted as it merely creates havoc in the communities.

ix. A comprehensive database on arsenic contaminated aquifers is a prerequisite, as is the need to build community participation for maintaining and monitoring the mitigation programmes. Thus making society responsible and knowledgeable can solve many problems associated with the water scarcity issues in the arsenic affected areas.

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