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Research Article

ASSESSMENT OF HUMAN VULNERABILITY TO GROUNDWATER ARSENIC AND IRON: A CASE STUDY ON BERHAMPORE BLOCK OF MURSHIDABAD DISTRICT, WEST BENGAL, INDIA

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ABSTRACT
Arsenic and iron are the common hazardous groundwater pollutant found in alluvial track of Berhampore block of Murshidabad district. Here, thousands of rural people are suffering from this problem of arsenic induced health diseases. Present study portrays the spatial distribution of arsenic and iron in tube wells using the Inverse Distance Weighting (IDW) interpolation technique. The vulnerable mouzas has been weighed up based on elevated arsenic or iron concentration and considering the density of population. The results revel that a major part of this block is exposed to arsenic and iron pollution. Finally, the study suggests taking suitable planning strategy to reduce the human vulnerability from the said groundwater contamination.

Key Words: *Inverse Distance Weighting, Human Vulnerability, Arsenic Contamination, Iron Hazard*.

INTRODUCTION
Arsenic contamination is the foremost problem in the interfluvial region of the Bhagirathi-Hugli and the Jalangi-Ichamati Rivers lying mostly in the eastern part of the Bhagirathi-Hugli river of West Bengal (Elangovan *et al.,* 2006) and many attempts have been made to analyze arsenic effects on human being in this region. In the Gangetic plain of West Bengal, thousands are suffering from arsenic toxicity and millions are at risk (Chakraborti *et al.,* 2004). Rahaman *et al.,* (2006) analyzed 16 years of water sample from nine arsenic affected districts of West Bengal and noted the districts of 24 Parganas, Nadia, Murshidabad and Malda as highly arsenic contaminated. NIH (National Institute of Hydrology) and CGWB (Central Ground Water Board) studied the block wise distribution of hand tube wells against arsenic concentration ranges in Murshidabad district, where 46.3 percent and 15.6 percent of total sample have arsenic concentration greater than 0.01 mg/L and 0.05mg/L respectively. Arsenic is one of such poisonous pollutant that found in drinking water in arsenite and arsenate toxic form and when it crosses the permissible limit of 0.05 mg/litre it has deleterious effects on human health (Elangovan *et al.,* 2006).
Although, iron in drinking water does not have significant effect upon health condition of people, U.S. Environmental Protection Agency (USEPA) has established a secondary maximum contaminant levels for various constituents present in drinking water and that is 0.3 mg/L for iron. Apart from that, Chakraborti *et al.,* (2009) assumes iron concentration above 0.3 mg/L as unacceptable in his study of status of groundwater arsenic contamination in the state of West Bengal. Ayotte *et al.,* (1999) in his discussion on relation of arsenic, iron, and manganese in groundwater stated that people who take water from private wells, are economically affected by the presence of iron in groundwater due to staining of clothes, household fixtures, deterioration of pipes and these also lead to growth of bacteria in drinking water. Hence, the two said elements are more or less harmful to the human being in causing serious health issues.
For a long since, various attempts have been made to measure or reduce the human vulnerability to natural hazards. In this regard human vulnerability assessment to the groundwater pollution is a technique that identifies the threatened people to any type of groundwater pollutant. The prime objective of the current paper is to examine the human vulnerability due to arsenic and iron hazards using GIS tools.

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About The Study Area

The study area lies between the 23º 55′ 44″ N to 24º 10′ 52″ N latitudes and 88º 08′ 38″ E to 88º 28′ 59″ E longitudes covering a total geographical area of 314.19 sq. km. comprising 18 GPs, one municipality and 144 Mouzas. According to the census 2001, the block has a total population of 3, 78,884. Here, a major part of population lives in rural area while only 6% people reside in main sadar town.

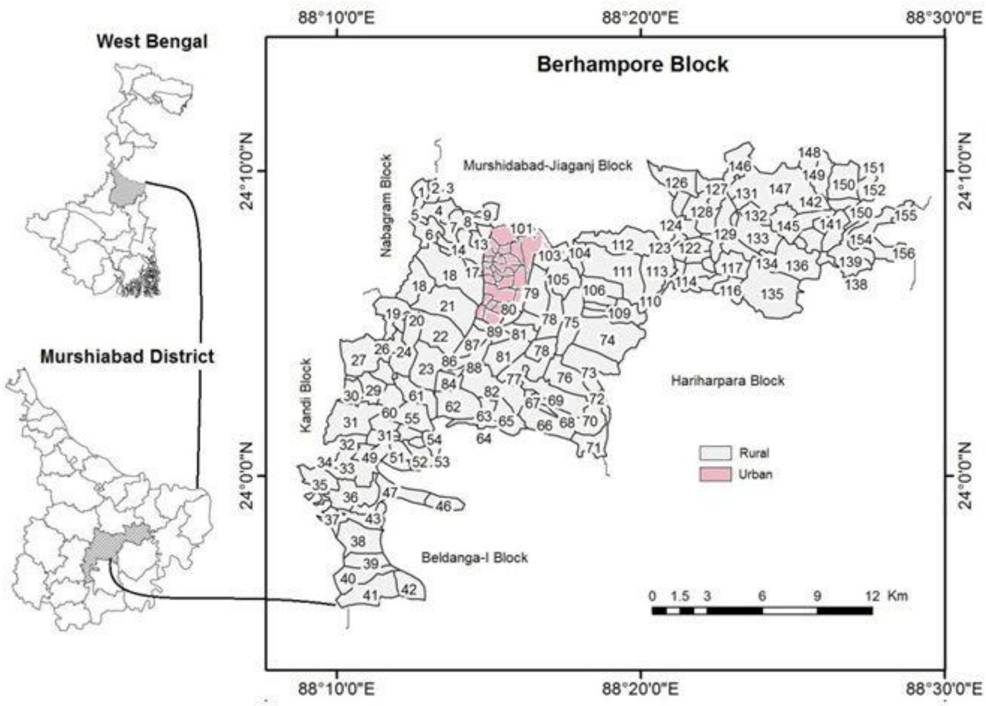

Fig. 1 Map depicting the Location of Berhampore Block along with its *Mouza* divisions

The study area is an ideal example of floodplain alluvial track where groundwater occurs in both semi-confined and unconfined conditions. The river Bhagirathi drains across north to south over the block. The arsenic polluted area in the district includes succession of upper Holocene Quaternary sediments where arseniferous tract lies mainly within shallow depth of 20–100 mbgl, is mainly made of sediment deposited by meandering streams (Mehta *et al*, 2009).

MATERIALS AND METHODS

The present study has been worked out based on different secondary data sources. The data concerning arsenic concentration in tube well water for the year 2010 were derived from *SEVABRATA*, a Non-Govt. Organization (NGO). Density of population for the various Mouzas and Wards has been acquired from Census of India (2001). A handheld GPS receiver has been used to collect the coordinates of the tube wells located in various locations over the block. The spatial distribution of arsenic and iron concentration in groundwater has been generated using the Interpolation technique. Here, Inverse Distance Weighting (IDW) interpolation algorithm of ArcGIS 9.1 has been used.

The mathematical notation for IDW is: $A_0 = \frac{\sum_{i=1}^{n} Ai \frac{1}{d_i^{\,p}}}{\sum_{i=1}^{n} \frac{1}{d_i^{\,p}}}$

Where, A_0 is the estimated arsenic concentration at (x_0, y_0 z_0), A_i is the known data value at (x_i, y_i, z_i), d_i is the distance between (x_0, y_0 z_0) and (x_i, y_i, z_i), p is the power, and n is the number of data points in the neighborhood of A_0. Here, a power of two has been used with IDW.

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Table 1: Reference List of *Mouzas* and their J.L. No. (Jurisdiction List Number)

J.L No.	*Mouza*	J.L No.	*Mouza*	J.L No.	*Mouza*	J.L No.	*Mouza*	J.L No.	*Mouza*
1	Laksanpur	31	Arazi Madhupur	60	Samaskar	90	Ajodhya Nagar (P)	129	Daulatabad
2	Diha	32	Dabkai	61	Sungai	91	Gar Baharampur (P)	130	Mukundapur
3	Nutangram	33	Kodla	62	Fate Singdiar	101	Kalikapur Kadamkhandi (P)	131	Goraipur
4	Debidaspur	34	Arazi Chhiruti	63	Mankara	103	Nagpara	132	Sadipur
5	Khili	35	Uttar Hijal	64	Math Binkar	104	Sibpur	133	Chutipur
6	Fatepur	36	Katalia	65	Baninathpur	105	Banjetia	134	Purbagopinathpu r
7	Bahara	37	Dakshin Hijal	66	Bezpara	106	Madapur	135	Selamatpur
8	Bagmara	38	Chumarigacha	67	Baikunthapur	107	Paschim Gopinathpur	136	Dadpur
9	Naoda	39	Bara Satui	68	Bhatpara	108	Kariagachhi	137	Gangaprasad
10	Raniswar	40	Bhagabanbati	69	Sundipur	109	Putijol	138	Nutanpara
11	Lakshmi Narayanpur	41	Chhota Satui	70	Naopara	110	Uday Nagar	139	Madanpur
12	Bundhai Para	42	Sona Diar	71	Simulia	111	Hati Nagar	140	Ruharpara
13	Nialish Para	43	Basabari	72	Panch Baria	112	Janmahammadpur	141	Baliharpur
14	Tikiapara	44	Gangadharpur	73	Rajdharpara	113	Usta	142	Habipur
16	Arazi Budharpara	45	Char Bhabanandapur	74	Purbba Narayanpur	114	Muliarazi	143	Dhanaipur

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17	Budharpara	46	Char Sujapur	75	Kharsadanga	115	Harirampur	144	Mirpur
18	Gopjan	47	Chak Katalia	76	Naoda Panur	116	Balia Danga	145	Sundalpur
19	Moktarpur	48	Chak Dangapara	77	Kaya	117	Purandarpur	146	Hogaldanga
20	Balarampur	49	Chhiruti	78	Tarakpur	118	Idilpur	147	Chhayghari
21	Andar Manik	50	Rangamati Chandpara	79	Sibdanga Badarpur	119	Chhota Garabasa	148	Hajidanga
22	Basudebkhali	51	Pakamati Mahula	80	Pakuria	120	Muli	149	Baradaha
23	Jagannathpur	52	Charmahula	81	Chaltia	121	Jhanjha	150	Kaladanga
24	Sahajadpur	53	Parhalalpur	82	Bairgachhi	122	Benidaspur	151	Ganti Baisnab Charan
25	Kandibandha	54	Parkhidirpur	83	Pashchim Narayanpur	123	Garabasa	152	Charislampur
26	Nischintapur	55	Jadupur	84	Char Narayanpur	124	Maharajpur	153	Garamgari
27	Bahurul	56	Char Halalpur	85	Bairgachhi Kanan Doem	125	Hanumanta Nagar	154	Nidhi Nagar Sarsabad
28	Bilchauti	57	Char Khidirpur	86	Char Begpur	126	Gauripur	155	Char Harharia
29	Majhira	58	Chak Chandpara	87	Haridasmati	127	Ruhia	156	Char Panchananpur
30	Gobindapur	59	Pratappur Chandpara	88	Belia Khari	128	Kulbaria		

Source: Census of India, 2001

After finishing the raster maps of arsenic and iron, 'Zonal Statistics as Table' tools of ArcGIS have been used to summarize the *Mouza* wise maximum values of the two groundwater pollutants into a single attribute table. Finally, the *Mouzas* have been categorized into an array of classes depending upon the extent of vulnerability to arsenic and iron using the MS Excel 2007. Added with it, various cartographic as well as statistical techniques have been adopted to illustrate the *Mouza* level spatial distribution patterns of said variable and the relationship.

RESULTS AND DISCUSSION

The data were collected from 117 tube wells spread over the study area from which the distribution map has been generated. In this study, inverse distance weighted technique has been applied for the two water quality data. About 85% of tube wells have experienced arsenic concentration beyond the WHO drinking water guidelines of 0.01 mg/L while about 33% have exceeded the BSI guidelines of 0.05mg/L. The spatial distribution of arsenic concentration in groundwater is illustrated in Figure 2.a. It is found that the arsenic concentration is not uniformly distributed over the study area; only the central part is highly arsenic prone.

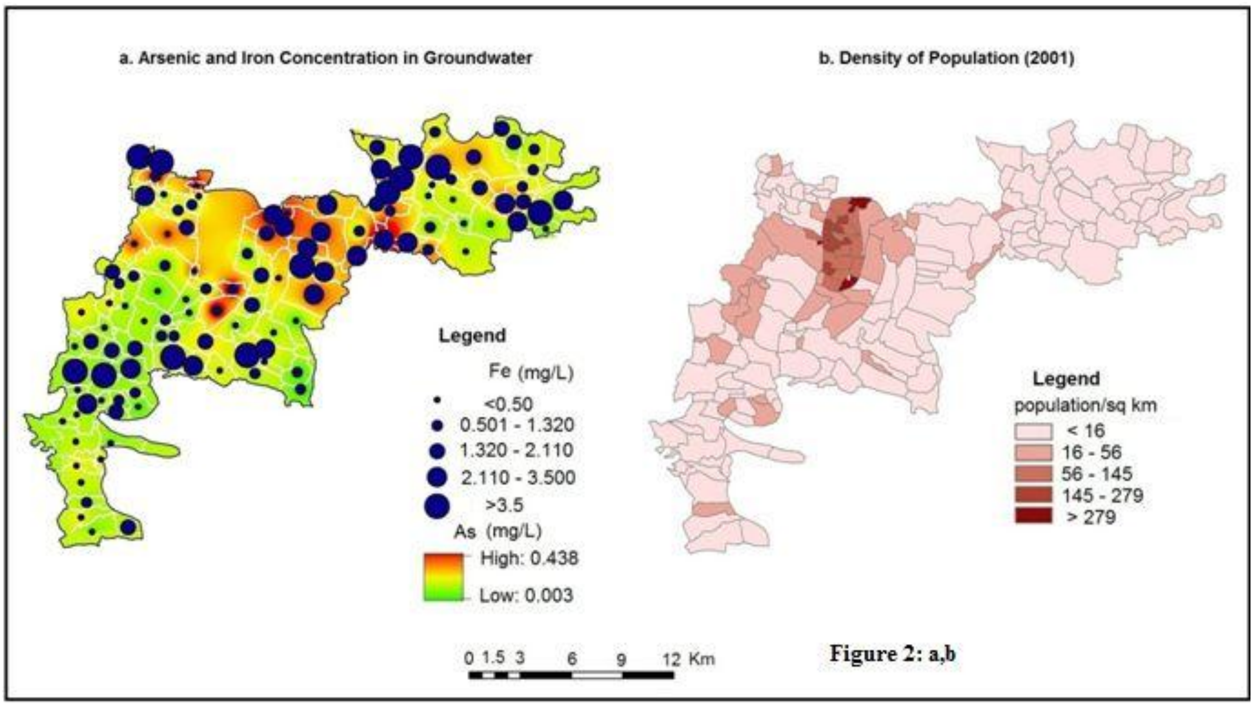

Figure 2: a,b

The Figure 2.a also portrays the iron concentration in groundwater. The map reveals the said G.P. has elevated iron concentration in groundwater in association with Arsenic. After such occurrence, it is noteworthy to justify the factual relationship between arsenic and iron. A simple Pearson's correlation has been worked out in such circumstance. The resulted value of r is 0.385, significant at the 0.01 level (2-trailed) which validate the poor association between arsenic and iron in groundwater. Chakraborti et al, (2009) analyzed 17050 water samples from the whole state of West Bengal for both arsenic and iron and reported that a poor relationship (r = 0.24, n = 17050) existed in the bi-variate data.

Vulnerability to Arsenic Hazard

In the study area, arsenic is the threatening toxicological element found in the tube well water. The problem of arsenic is now more serious in the *mouzas* of high population density than uninhabited area. Greater population density also plays a role to increase the vulnerability in terms of increasing the population pressure to the hand tube wells that led to the massive withdrawal of groundwater. Thus, the diurnal fluctuation of water table has a direct influence in the leaching of arsenic to water. Considering the two variable, the mouzas have been grouped into different vulnerable zones. The worse affected *mouzas* are Sibdanga Badarpur (79) Banjetia (105), Kalikapur Kadamkhandi (101) of Manindranagar G.P., Chaltia (81), Ajodhya Nagar (89), of Bhakuri II G.P., Gopjan (18), of Radharghat-I G.P. where an elevated arsenic concentration (above 0.10 mg/L) has been occurs in tube well with having the population density high. The other highly vulnerable *mouzas* are Nagpara (103), Sibpur (104), Madapur (106), Hati Nagar (111), Madpur (106), Janmahammadpur (112), Usta (113), of Hatinagar G.P., Purba Narayanpur (74), Kharsadanga (75), Paschim Gopinathpur (107), Kariagachhi (108), Putijol (109), Uday Nagar (110), of Rahdharpara G.P., where arsenic concentration exceeds 0.05 mg/L but population density is not upto the mark. However, population density does not pose any serious condition there but this area has been used for boro paddy cultivation that requires huge groundwater for the irrigational purpose. It was scientifically proved that trace elements of arsenic could reach human body through food chain. Therefore, elevated arsenic in area of agricultural landscape may also pose threat to the human being.

Vulnerability to Iron Hazard

However, there is no health-based guideline value for iron in drinking water has been proposed by WHO, but economic effects of occurrence of iron in well has been stated earlier, An elevated iron concentration also supports the growth of bacteria in drinking water that may cause various types of diseases. Thus, human vulnerability is greater in the regions where iron in well water is maximum along with high density of population. The worse condition is found Sibdanga Badarpur (79) Banjetia (105), Kalikapur Kadamkhandi (101) of Manindranagar G.P., Chaltia (81), Ajodhya Nagar (89), of Bhakuri II G.P., Gopjan (18), of Radharghat-I G.P., Nagpara (103), Sibpur (104), Madapur (106), Hati Nagar (111), Madpur (106), Janmahammadpur (112), Usta (113), of Hatinagar G.P., Purba Narayanpur (74), Kharsadanga (75), Paschim Gopinathpur (107), Kariagachhi (108), Putijol (109) of Rajdharpara G.P. where iron concentration is above 2.11 mg/L. The people in this *mouzas* are highly vulnerable to iron and arsenic hazard and consequently overall vulnerability reaches to maximum for the said region. In the southern part of the block Arazi Madhupur (31), Dabkai (32), Rangamati Chandpara (50), Pratappur Chandpara (59) mouzas of Rangamati chandpara G.P., Fate Singdiar (62) of Rarisdasmati G.P., Baikunthapur (67) Sundipur (69) of Nowdapanur G.P., Dhanaipur (143) Madanpur (129) of Madanpur G.P. Goraipur (131) Chhayghari (147) *mouzas* of Chhaighari G.P. are severally affected by iron hazard.

The term vulnerability varies from man to man based on the status of human settlement and their infrastructure. Therefore, the people in urban area having higher economic condition can reduces the arsenic or iron hazard through the application of modern preventing measures on the other hand, the rural poor people unable to take such measure are more exposed to those hazards. Form the Fig. 2.a. it is clear that the arsenic distribution is moderately high throughout the Berhampore municipality. The word no. 2, 4, and 7 has an elevated arsenic concentration in groundwater. The people in this urban centre gets the purified water from the municipal water plant otherwise they collects groundwater from deeper aquifer, which is less affected by arsenic. Considering the above said, human vulnerability in the municipal area is less relevant in the context of present study.

CONCLUDING REMARKS

Although usage of groundwater started from the early human society but in the recent days, the intensity of groundwater usage has been accelerated due to the progress of human civilization industrialization, and agricultural revolution. Such increasing rate of groundwater usage aids to the introduction of groundwater pollution related several health diseases to the common people. Groundwater contamination by arsenic is a major health problem that has been common in several regions of the world, especially in the Bengal delta of South Asia (Winkel *et al.*, 2011). In this circumstances, mapping of the groundwater contaminant and vulnerability measurement are the best techniques to the decision maker for implementing suitable remedial measures. The present study portrays a *mouza* wise representation on human vulnerability to the arsenic and iron hazard in Berhampore block of Murshidabad district. Since, the extents of preceding hazard are quite frequent in rural area; there is dire need of suitable remedies to provide safe and hygienic drinking water to poor rural commoner and thus reducing the possible vulnerability of this people. Raising awareness about water management in house hold level can reduce the large scale abuse of water. In addition, appropriate technical assistance should be needed to use the water of nearby perennial river Bhagirathi for the purpose of domestic work and agricultural activities rather using the ground water for the said purpose. The administration, mainly Public Welfare Department (P.W.D) should come forward enthusiastically to collaborate with *UNICEF* regarding various projects for the establishment of arsenic free deep tube well in rural countryside.

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