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Status of ground water quality in selected shallow aquifers of Saharsa district, the Kosi megafan, the North Bihar Plains

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Abstract

Water is one of the most indispensable resource and the elixir of life. Ground water is one of the major source of drinking water in India and therefore, it plays a vital role in human health. Generally, ground water is extracted through hand pump in Saharsa district (The Kosi megafan, The North Bihar Plains). Geogenic and anthropogenic activities are the two factors responsible for the quality degradation of ground water. Excessive ground water extraction for agriculture, industries and domestic utilization, made it liable to deterioration. Keeping these considerations, a study was conducted to evaluate the physio-chemical properties viz., pH, EC, turbidity, hardness, alkalinity, TDS, chloride, fluoride, nitrate, sulphate and iron of water samples obtained from the 10 blocks namely Sattarkatiya, Saurbazar, Kahra, Pattarghat, Navhatta, BanmaIthari, Salkhua, Mahishi, Simri-Bakhtiyarpur and Sonbarsa and the urban region (city part) of Saharsa district, Bihar. Among the various parameters, iron and fluoride content in some locations were found surpassing the permissible limit. The parameters were analyzed and compared with the standards values as prescribed by American Public Health Association (APHA), World Health Organization (WHO), Bureau of Indian Standards (BIS) and Indian Council of Medical Research (ICMR). General recommendation as the permissible limits for iron is 0.3-1 mg/L and fluoride is 1.0-1.5 mg/L. However, status of iron and fluoride in the study area were found in the range of 0.3-4.1 mg/L and 0.2-1.5 mg/L respectively, which shows that there is a requirement of holistic approach to improve the quality of ground water.

Keywords: Ground water, water quality standards, physico-chemical parameters, correlation studies.

Water is the most essential substance for existence of life on earth. Ground water quality has become an important water resources issue due to rapid increase of population, rapid industrialization, unplanned urbanization, flow of pollution from upland to lowland, and overuse of fertilizers and pesticides in agriculture (Joarder, 2008). The major problem with the ground water is that once contaminated, it is very difficult to restore its quality. Hence, there is a need to concern for the protection and management of ground water quality. It is well known that no straight forward reasons can be advanced for the deterioration of water quality, as it is dependent on several water quality parameters (Gajendran *et al*. 2013; Jothivenkatachalam *et al*. 2008).

During the past two decades, the water level in several parts of the country has severely fallen due to increased extractions (Gleick, 1993). Main sources of drinking water are surface water and underground water resources (Berner, 1987). The number of wells drilled for irrigation of both food and cash crops have rapidly and indiscriminately increased. India's burgeoning population and changing lifestyles has also increased the domestic need for water (Rao, 1997). Water provides goods (e.g. drinking-water, irrigation water) and services (e.g. hydroelectricity generation, recreation and amenity) that are utilized by agriculture, industry and households. It is the prime medium in which physical and chemical transformations, particularly those of biological significance take place. Various physico-chemical parameters have a significant role in determining the potability of water . Physico-chemical quality of any water body is the major deciding factor of the pattern of aquatic biota as well as primary and secondary productivity. Water as the most important component of environment plays a key role in maintaining the integrity of the entire ecosystem. The main source to fulfill the demand for irrigation, industrial and drinking purposes is ground water. About 95% of the total available water all over the world is in the form of ground water. The pollution of air, water, and land has an affect on the pollution and contamination of groundwater (Ciaccia, 1972). The solid, liquid, and the gaseous wastes that are generated, if not treated properly, result in pollution of the environment which also affect groundwater due to the hydraulic connectivity in the hydrological cycle (Bandy, 1984). Thus, the quality of ground water is of vital concern for mankind, since it is directly linked with human welfare. Rapid increase of population, urbanization, agricultural practices and several human activities are polluting the fresh water resource by adding a lots of pollutants. Abnormal increase in the arsenic, fluoride and iron content from its normal value can stance serious problem.

Main source of drinking water is ground water in the whole Saharsa district, which is largely extracted using hand pumps. Divisional headquarter of Koshi Division is Saharsa city which is situated 95 km away from the Koshi river, known as "Bihar Ka Shok" (Sorrow of Bihar) (Singh, 2009) which usually causees an extensive soil erosion and landslides in fertile agricultural lands, thereby disturbing the water quality and rural economy of the region. Water pollution in this region has also been created due to lack of knowledge, negligence and illiteracy. In order to meet the rising water needs, evaluation of water quality is important for its allocation to various uses (Abbasi, 1999). According to WHO (2003), about 80% of all the diseases in human beings are caused by contaminated water. Hence, in the present study, an attempt was made to evaluate the quality of ground water in Saharsa District and thereby estimate different physio-chemical parameters of ground water which could be of enormous educational value for the area.

MATERIALS AND METHODS

The present investigation involved a field sampling in Saharsa district of Bihar followed by laboratory analysis of the water samples in the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi.

Description of the site

The study area forms a part of Saharsa district in Bihar, located at a distance of 240 km northeast of the state capital of Patna. Geographically, it is located at 25°88′0″ N latitude and 86°6′0″ E longitude on alluvial plains of river Tilawe. The area is characterized by high rainfall, warm and temperate climate. The average annual temperature is 25.2°C and average annual rainfall is 1095 mm. Precipitation is the lowest in December, with an average of 1 mm. Most of the precipitation here falls in August, averaging 269 mm. At an average temperature of 30.4°C, May is the hottest month of the year. January is the coldest month, with temperatures averaging 16.6°C. Between the driest and wettest months, the difference in precipitation is 268 mm throughout the year and temperature varies by 13.8°C.

Sampling

Groundwater samples were collected from ten blocks of Saharsa districts (figure 1) in Bihar namely Sattarkatiya, Saurbazar, Kahra, Pattarghat, Navhatta, BanmaIthari, Salkhua, Mahishi, Simri-Bakhtiyarpur and Sonbarsa and the urban region (city part of Saharsa district). The samples are collected from hand pump during (Oct 2015 - Feb 2016) from various locations from village, temple, school, chowck, market, bus stop, railway station and other different public places. The hand pumps were continuously pumped prior to the sampling to ensure that ground water to be sampled was representative of ground water aquifer. Water samples were collected in high-density polethylene (HDPE) bottles and stored at 4°C and for laboratory analysis.

Physico-chemical analysis

The physico-chemical analysis of the collected water samples were performed by following standard procedures (Choduhury *et al*. 2012; APHA, 1992). The pH and electrical conductivity (EC) were measured by using Systronics digital pH meter (Model No. 335) with an accuracy of (± 0.01) and Systronics digital conductivity meter (Model No. 304) with an accuracy of (± 0.01) respectively. Total alkalinity (TA) was estimated by neutralizing with standard HCl acid. Total hardness (TH) and calcium (Ca) were measured by EDTA titration method (Honda, 1986). Total dissolved solids (TDS) was estimated by ionic calculation method. Chloride was measured volumetrically by silver nitrate titrimetric method using potassium chromate as indicator and was calculated in terms of mg/L (Manivasakam, 2005). Sulphate was measured by gravimetric method using barium chloride as precipitating agent. Iron (Fe) was estimated by standard stock solution of ferrous ammonium sulfate, hexahydrate and 0.25% ortho-phenanthroline solution and the absorbance was taken by using atomic absorption spectroscopy method. Nitrate content in ground water was determined electrochemically using the EDT direct ion selective electrode methods. Fluoride was estimated by using an ion selective electrode with 720 pH/ISE meter.

Statistical analysis

All the data were statistically analysed using software packages (SPSS-Version 13) and Microsoft excel. The mean and standard deviations were calculated to know the chemical parameters which are deviating from the WHO and other organisations standardes. Correlation analysis was used to establish the nature of the relationship between the water quality parameters.

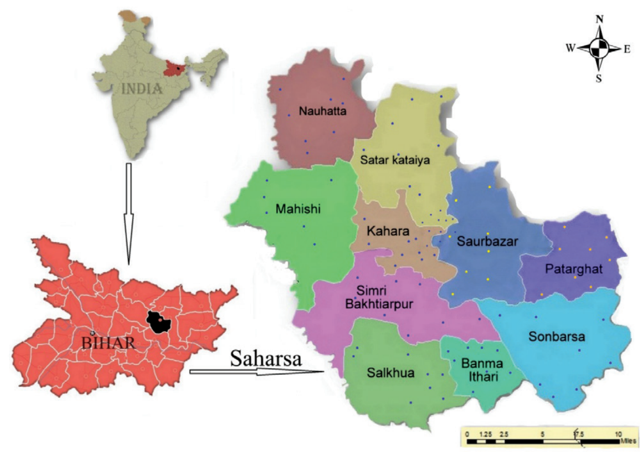

Fig. 1: Map of the sampling sites of Saharsa, Bihar

Results and discussion

Physico-chemical parameters

pH is an index of the amount of hydrogen ions (H^-) that are present in a substance. In the present study, pH ranged from 6.59 (Navhatta Block) to 7.30 (Saurbazar Block) in Saharsa district of Bihar (Table 1). According to BIS (2003), the permissible limit of pH for water is from 6.5 to 8.5 and results of the study area ranged within that limit. The pH value of drinking water is an important index of acidity and alkalinity. pH below 6.5 corrodes pipes. Block wise analysis of water samples for EC revealed that maximum value was observed in Saurbazar block (0.60 dsm^{-1}) and minimum value in Salkhua block (0.30 dsm^{-1}). Maximum turbidity value was observed in Simri-Bakhtiyarpur (10.13 NTU) and minimum value in Navhatta (6.63 NTU). According to BIS (2013) the permissible limit of turbidity for water is from 5 to 10 NTU but, the data obtained in Saharsa city (17 NTU) was more than the permissible limit. The desirable limits for hardness in drinking water according to ICMR is 300 - 600 mg/L and block wise data of all the samples were found to be less than the permissible limit i. e., maximum value (249.38 mg/L) was observed in Saurbazar and minimum value (127.6 mg/L) in Salkhua. According to BIS (2003), the desirable limit for alkalinity is 200-600 mg/L. However from this experiment, maximum value (143.76 mg/L) was recorded in Saharsa city and minimum value (24.25 mg/L) in Navhatta. Water with high TDS indicates more ionic concentration, which is inferior and can cause physiological disorders to its users (Rao, 2002). The TDS values of water samples were found to be less then desirable limit of WHO, 2009 (500- 1000 mg/L). However, the maximum TDS value (385.26 mg/L) was of Saurbazar block and the minimum TDS value (198 mg/L) was of Salkhua block. Chloride salts, being highly soluble and free from chemical reactions with minerals of reservoir rocks, remain stable once they enter in solution. Most chloride in groundwater is present in sodium chloride, but the chloride content may exceed the sodium due to base-exchange phenomena. According to BIS, the permissible limit of chloride in drinking water is 250 - 1000 mg/L. The maximum value (107.50 mg/L) of chloride was obtained in Mahishi block and minimum value (21.50 mg/L) in BanmaIthari block. Excessive iron content makes the water turbid, discolored and imparts an astringent taste to water. As per the standards set by WHO (1984), the permissible level of iron is 0.3 mg/L and above 1.00 mg/L of iron in drinking water is not considered suitable for drinking purposes. The maximum contamination of iron was in Saharsa city (3.95 mg/L) and minimum in Sattarkatiya (1.23mg/L).

Carbonate rocks are the chief source of calcium in natural water. The limits of calcium as prescribed by BIS (2003) is 75-200 mg/L. The maximum and minimum values were recorded in Saurbazar (56.75 mg/L) and Kahra (25 mg/L) respectively. The sulphate content of ground water is increased through oxidation and precipitation processes. The limit for sulphates in drinking water, according to BIS (2013) is 200 mg/L to 400 mg/L. Block wise data revealed that maximum value is observed in Banma Ithari block (29.125 mg/L) and minimum value in Saharsa City (14.13 mg/L). McKee (1963) reported that high concentration of sulphate may induce diarrhoea. Nitrate nitrogen is one of the major constituents of organisms along with carbon and hydrogen as amino acids, proteins and organic compounds present in the bore wells water (Miller, 1981). Nitrate was standardized by the BIS (2013) as 45 mg/L of water. Nitrate levels in Saharsa District were less than 45 mg/L of groundwater. In the present study (Table 1.1), the average maximum value of NO_3^- was observed in Navhatta block (12.5 mg/L) and minimum value (6.25 mg/L) in Salkhua block. The nitrate concentration in ground water was normally low for all the samples, but could reach high levels from agricultural runoff, or from contamination by human or animal wastes, which was evident from the data. Abnormal level of fluoride in water is due to presence of fluorine-bearing minerals. The desirable limit for fluoride in drinking water as prescribed by BIS (2003) ranges from 1.0-1.5 mg/L. The maximum value (0.99 mg/L) was observed in Saurbazar Block and minimum value (0.35 mg/L) was obtained in Salkhua Block. The source of fluoride in these water samples may be weathering of rocks, phosphatic fertilizers used for agriculture and/or the sewage sludge.

Correlation studies

In this study, the numerical values of correlation coefficient, R for the twelve water quality parameters, are tabulated in Table 2 to show that a single parameter analyzed has relationship with other parameters. The pH of water is a measurement of the concentration of hydrogen ions (H^+) in solution. Since pH has no direct effect on plant growth, it does affect the form/ availability of nutrient elements in irrigation water, fertilizer solutions and the growing medium. pH shows highly significant positive correlation with Ca (r=0.387**) and F (r=0.344**) and negative correlation with Cl (r= -0.070), NO_3^- (r= -0.073), SO_4^{2-} (r= -0.044) and Fe (r= -0.113). There exist negative correlation between iron and pH and due to solubility of iron in water with its hydroxyl ion which increases free hydrogen ion and subsequently decreases the pH (Metzger, 2005). Similarly, the negative correlation between fluorine and pH might be due to the mineral exchange of its hydroxyl ion for fluoride. The electrical conductivity (EC) of water depends upon

Table 1: Salient physico-chemical parameters of hand pump water in different blocks of Saharsa District, Bihar

Sr. No	Block		pH	EC	Turbidity	(mg/L)								
						TH	Alkalinity	TDS	Cl	Fe	Ca	SO_4	NO_3	F
1	Saharsa City	Mean	6.90	0.41	10	156.63	143.75	305.00	55.88	2.95	34.88	14.13	10.50	0.75
	n=08	S.D	0.39	0.16	3.99	40.61	39.28	117.29	32.47	0.93	7.82	3.76	4.03	0.16
		Range	6.56-7.84	0.25-0.66	5-17	96-220	91-201	180-501	22-130	1.5-4.1	22-44	8-20	5-20	0.5-1
2	Sattarkatiya	Mean	6.91	0.37	7.56	201.0	180.96	249.0	39.33	1.23	40.89	20.67	9.33	0.82
	n=9	S.D	0.19	0.12	20.6	66.93	11.93	77.71	27.52	0.61	15.11	7.53	4.97	0.29
		Range	6.62-7.16	0.189-0.532	5-10	120-328	90-130	126-355	11-80	0.5-2.1	24-72	10-32	5-20	0.5-1.5
3	Kahra	Mean	6.85	0.49	8.75	198.63	39.75	328.38	76.63	2.63	25.00	21.00	10.63	0.44
	n=8	S.D	0.36	0.37	1.56	91	15.43	249.08	45.49	0.99	14.53	6.00	3.81	0.13
		Range	6.41-7.52	0.12-1.03	5-10	122-362	21-71	84-691	30-170	0.9-4.1	8-48	13-31	5-17	0.2-0.6
4	Saurbazar	Mean	7.34	0.59	8	249.37	91.87	385.25	72.25	1.6	56.75	20.37	8	0.98
	n=8	S.D	0.34	0.39	2.29	72.49	84.07	266.58	52.79	0.98	22.25	7.78	2.12	0.26
		Range	6.91-7.91	0.21-1.28	5-12	160-381	30-260	143-855	21-180	0.5-3.8	31-96	10-32	5-10	0.6-14
5	Pattarghat	Mean	6.80	0.50	7.75	177.50	103.25	335.88	56.38	2.21	41.63	22.25	10.00	0.49
	n=8	S.D	0.15	0.25	2.05	95.09	14.39	164.14	36.66	0.79	17.77	4.18	6.12	0.13
		Range	6.54-7	0.29-1.01	5-10	96-370	80-124	197-678	12-126	1-3.2	18-65	16-30	5-20	0.2-0.6
6	Navhatta	Mean	6.65	0.39	6.63	131.25	24.25	257.63	45.50	2.11	25.25	28.38	12.5	0.56
	n=8	S.D	0.21	0.07	1.80	31.10	5.99	47.62	10.01	1.05	8.81	6.59	5.10	0.22
		Range	6.45-7.15	0.295-0.502	5-10	94-188	17-38	197-335	30-66	0.3-3.2	16-42	20-41	5-20	0.2-0.8
7	Banmaithari	Mean	7.04	0.46	8.50	169.50	105.63	304.13	21.50	2.46	49.25	29.13	10.00	0.51
	n=8	S.D	0.13	0.11	1.73	51.36	12.99	73.76	8.82	0.97	12.78	8.46	6.12	0.19
		Range	6.8-7.2	0.27-0.615	5-10	94-252	89-124	180-410	12-42	1-3.6	32-72	15-40	5-20	0.2-0.8
8	Salkhua	Mean	6.87	0.30	6.75	127.50	106.13	198.00	97.50	1.34	35.75	17.50	6.25	0.35
	n=8	S.D	0.27	0.14	2.11	31.43	11.54	92.09	21.07	0.74	10.01	3.54	2.17	0.12
		Range	6.54-7.23	0.13-0.597	5-10	94-190	90-122	90-398	60-120	0.4-2.9	20-56	10-20	5-10	0.2-0.6
9	Mahishi	Mean	6.81	0.51	7.60	208.20	91.40	338.80	107.40	1.84	34.40	19.00	7.00	0.48
	n=5	S.D	0.25	0.17	1.62	39.86	15.63	111.55	24.75	1.25	6.50	2.00	2.45	0.13
		Range	6.63-7.16	0.29-0.67	5-10	130-241	65-112	199-448	76-140	0.3-3.9	28-44	15-20	5-10	0.3-0.7
10	Simri	Mean	6.97	0.32	10.13	133.50	115.00	247.63	36.25	2.05	30.25	21.38	9.75	0.54
	Bakhtiyarpur	S.D	0.29	0.07	2.20	30.83	38.57	84.44	18.03	0.85	9.98	5.45	4.76	0.19
	n=8	Range	6.64-7.64	0.16-0.44	8-10	105-195	80-210	100-400	12-66	0.4-2.9	18-52	12-30	5-19	0.3-0.20
11	Sonbarsa	Mean	6.75	0.34	7.75	171.88	129.13	226.25	73.75	1.43	34.00	18.50	7.63	0.56
	n=8	S.D	0.24	0.10	1.98	36.23	15.34	69.85	32.76	0.62	11.14	6.24	2.45	0.20
		Range	6.42-7.12	0.13-0.49	5-10	91-215	90-142	92-329	30-140	0.3-2.4	16-52	10-30	5-11	0.3-0.9

Table 2: Correlation matrix between pHysico-chemical properties of hand pumps water

	PH	EC	Turb	TH	Alkalinity	TDS	Cl	Ca	SO_4	NO_3	F	Fe
pH	1	0.114	0.147	0.164	0.023	0.201	-0.070	0.387**	-0.030	-0.073	0.344**	-0.113
EC		1	-0.044	0.795**	-0.038	0.968**	0.551**	0.584**	0.024	0.098	0.082	-0.009
Turb			1	-0.027	0.201	-0.021	-0.320**	0.039	-0.161	0.142	0.061	0.289**
TH				1	0.047	0.752**	0.447**	0.645**	-0.075	0.017	0.103	-0.106
Alkalinity					1	-0.006	-0.078	0.106	-0.184	-0.080	0.134	-0.145
TDS						1	0.519**	0.579**	0.026	0.118	0.106	-0.008
Cl							1	0.183	-0.304**	-0.179	-0.127	-0.103
Ca								1	0.008	-0.044	0.144	-0.152
SO_4									1	-0.004	0.030	-0.083
NO_3										1	-0.153	0.260*
F											1	-0.065
Fe												1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

the concentration of ions and its nutrient load. EC is a measure of capacity of a substance or solution to conduct electricity. It is an excellent indicator of total dissolved solids and of salinity, which affects taste of potable water (Harilal *et al*. 2004). EC showed highly significant positive correlation with TH (r = 0.795**), TDS (r = 0.968**), Cl (r = 0.551**), Ca (r = 0.584**) and F (r = 0.584**). EC (Table 2) shows negative correlation with turbidity (r = -0.044), alkalinity (r = -0.038) and Fe (r = -0.009). EC showed non-significant correlation with SO_4^{2-}, NO_3^- and F.

Turbidity showed highly significant positive correlation with Fe (r=0.289**) and negative correlation with TH (r = -0.027), TDS (r = -0.021) and SO_4^{2-} (r= -0.161). Turbidity also indicated negative but significant correlation with Cl (r = -0.320**). However, it showed non-significant correlation with alkalinity, Ca, NO_3^- and F.

Total hardness (TH) of water is caused by the presence of salts of calcium and magnesium (Kataria *et al*. 2011). Highly significant positive correlations were found between TH and TDS (r = 0.752**), Cl (r = 0.447**) and Ca (r = 0.645**). TH showed negative correlations with SO_4^{2-} (r = -0.075) and Fe (r = -0.106) and non-significant correlation with alkalinity, NO_3^- and F (Table 2).

Total Dissolved Solid (TDS) showed highly positive significant correlation with Cl (r = 0.519**), Ca (r = 0.579**), and non-significant negative correlation with Fe (r = -0.008). TDS showed non-significant correlation with SO_4^{2-}, NO_3^- and F. High levels of residue in water make it unfit for drinking. Calcium (Ca) showed negative correlation with NO_3^- (r = -0.044) and Fe (r = -0.152). SO_4^{2-} showed negatively correlation with NO_3^- (r = -0.004), Fe (r = -0.083) and F (r = -0.153). F showed negatively correlation with Fe (r = -0.065). Managemental practices and soil mineral constituents are responsible for such types of variation.

Conclusion

From the above study, it is clear that maintenance of ground water quality is one of the primary requisite for good health. The average ionic composition demonstrate Ca>Fe and Cl>SO_4>NO_3>F trend in the cations and anion respectively. The pH, EC, TDS, Ca, Cl and SO_4 concentrations in the stream waters were recorded between desirable limit and permissible limit of WHO. The nitrate concentration in ground water was normally low for all the samples, but improper practices like excess use of nitrogenous fertilisers in agricultural lands could raise its level. In 10 blocks of Saharsa district including urban area of Saharsa city it was found that about 83% of total samples were contaminated with excess iron concentration (>1 mg L^{-1}). Excessive iron content makes the water turbid, discoloured and imparts an astringent taste to water due to which it cause severe problems to domestic purposes and hence its presence in drinking water is objectionable for various reasons. 7% of samples were found to be contaminated with fluoride content (>1.5 mg L^{-1}) and 22% samples were affected by turbidity (>10 NTU). Hence, the study indicates an immediate protective measure must be put in to action in the study area to improve the water quality of Saharsa district. The problem could be solved by adopting different government policies, educating the rural population and creating awareness by conducting campaigns etc. It is the basic duty of every individual to preserve and protect the water resources.

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