Geospatial Assessment of Fluoride Contamination in Groundwater and Health Hazard impacts in Bhagalpur Municipal Corporation Area, Bhagalpur, Bihar

[1]Kumari Gouri, [2]Manish Kumar*

University Department of Botany, T. M. Bhagalpur University, Bhagalpur-812007, India,
University Department of Zoology, T. M. Bhagalpur University, Bhagalpur-812007, India.

Abstract: The study present study has been conducted in Bhagalpur Municipal Corporation (BMC) area of Bhagalpur district which is situated in middle of Gangetic plain. This area is very famous for the geogenic contamination of fluoride. The investigation was undertaken in all the 51 wards between 2010-12 for parameters like pH, EC, TDS, TH, bicarbonate, nitrate, Phosphate and especial consideration was given to fluoride. During study it was found that the pre-monsoon season data of groundwater has more contamination levels of physico-chemical parameters, while fluoride contamination was observed higher in mid-monsoon period. Among the wards 39-51 which is in extreme southern part of BMC has higher values of fluoride levels in compare to the northern parts. The water quality of all the wards are contaminated with fluoride and showed adverse effect on residents. During the assessment of health impacts it was observed that the child and women population was more prone to fluoride based disease like dental and skeletal fluorosis. All the sampling points were digitized and mapped on Q-GIS which showed that the significant correlation with ward wise fluoride contamination level and affected people number in each wards.

Index Terms **– GIS mapping, Fluoride, Groundwater contamination, Bhagalpur, Fluorosis.**

I. INTRODUCTION

Groundwater quality is influenced by both the natural and anthropogenic activities (Kouras *et al*., 2007). Groundwater has been considered as suitable and safe source of water from ancient times. It is considered to be free from the direct contamination by surface flow due to the geological filters i.e. soil, that remove pollutants from water when it percolates during recharge (Prasad and Bhagan, 2004). Gigantic growing human population has increased the demand for water to the extent that it has brought tremendous pressure on water resources. The unprecedented demands for various purposes like agriculture, industries, households etc., have led to the disturbance in water table status in the overall the earth. In recent years, the groundwater resources degraded at higher extent that created serious health hazards in the present civilization.

The quality of water is described by its physical, chemical and microbiological characteristics. These characteristics are many and are interlinked (Samson *et al*., 2005). In India where groundwater is used extensively for irrigation and industrial purposes, a variety of byproducts, effluents, etc., are mixing to the groundwater at point and non-point sources that contaminating and resulting pollution of this precious resources. It's over exploitation is one the major causing factor for aquifer contamination in certain instance because of the easy availability and no fixed rule by the Government (Kumar and Shah,2006).

Keeping these facts the present study was planned for the Bhagalpur Municipal Corporation (BMC) area to evaluate the groundwater contamination especially fluoride and its impact on the human health. Bhagalpur is globally known for the fluoride contamination in its groundwater and people suffering from fluoride based disease mostly due to unawareness and sometimes with no evidence. This study will help to evaluate the extent of contamination and related health issues which will be key guide for the management authorities to develop new plan for the city while designing for smart city program.

II. STUDY AREA

Bhagalpur city is situated almost at the eastern fringe of middle Ganga plain. The city is thickly populated and is divided into 51 wards administered by the municipal corporation. Groundwater (shallow and deep bore wells) is the measure source of drinking water in the city and is the main source of intake of fluoride. The present study is proposed to gain insight in to temporal distribution and factors that influence the fluoride concentrations in the shallow and deep aquifers of alluvial terrain of Bhagalpur Municipal corporation area of Bhagalpur district of Bihar.

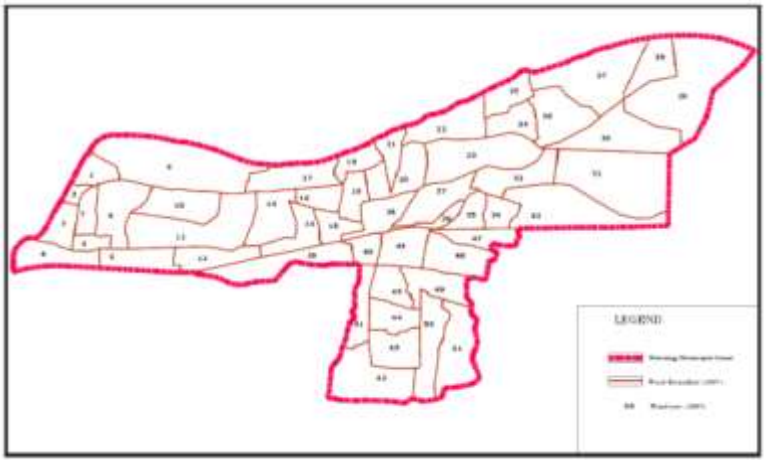

Figure 1: Location map of Bhagalpur Municipal Corporation area with 51 wards demarcation (source: adb.org)

III. MATERIAL AND METHODS

Groundwater samples were collected from the 51 wards during pre-monsoon, post monsoon and in monsoon season (2010-12). The characteristics such as water temperature, pH, electrical conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Bicarbonate (HCO_3^{2-}), Chloride (Cl^-), Nitrate as NO_3^-, Phosphates PO_4^- and fluoride (F^-) were studied. The parameters like EC, pH, TDS, and bicarbonate were measured in the field immediately after sampling. Rest of the parameters was analyzed in the Environmental laboratory of University Department of Botany, T. M. Bhagalpur University, Bhagalpur. The standard methods were tabulated in Table -1. The BIS limits of drinking water quality of utilization were compared with results.

Table 1: Methodology adopted for Physico-chemical analysis and BIS limits for drinking water quality parameters

Elements	Characteristics	Analytical method- unit	BIS limits 2012
General	pH	pH-digital meter	6.5 to 8.3
	Electrical conductivity	Conductivity-TDS meter - µs/cm	3000
	Total dissolve solids	Conductivity-TDS meter - mg/L	2000
	Total hardness as ($CaCO_3$)	EDTA Titrimetric - mg/L	600
Major ions	Bicarbonates as HCO_3^-	Titrimetric - mg/L	NA
	Chloride as Cl^-	Argentrometric - mg/L	1000
	Nitrate as NO_3^-	Phenol-Disulphonic acid - mg/L	45
	Phosphates PO_4^-	Stannous Chloride - mg/L	0.3
	Fluoride as F^-	Spectroquant Colorimeter Picco - mg/L	1.5

*All parameters are expressed in mg/l except Temperature (°C) and pH

IV. RESULT AND DISCUSSION

The data generated from chemical analysis of drinking water samples collected from the study area are tabulated in Table 2-3. Groundwater samples collected from the study area were clear without any visible colour, odor and turbidity. Among the other parameters the pH values ranging 6.8 to 8.4 in first year while it was 7 to 8.1 in the second year of study. The pH was observed much fluctuating in mid-monsoon seasons of both years having average of 7.4 and least was recorded in pre-monsoon seasons. The variation in pH is may be due to the condition of earth and minerals. The lower value in pre-monsoon indicates dilution due to less influx of percolation water of lower alkalinity.

EC conductivity is generally increased along a groundwater flow path because of the combined effect of the evaporation, ion exchange and topographic condition. In the present study, EC ranged 156.4 to 7452 µs/cm in first year and it slightly decreased 272.8 to 2533.1 µs/cm in second year. The highest average 1618.5 µs/cm was recorded from pre-monsoon season in 2010-11 during the present study which may be due to high rate of abstraction of water from weathered rocks may dissolved and solute increases the conductivity.

The value of total Hardness is more than total alkalinity which indicates that the groundwater is characterized by non-carbonate hardness and attributed to the presence of alkaline earth. It ranged between 101 to 1164 mg/L in 2010-11 and 101 to 1084.6 mg/L in 2011-12. The hardness summarized with highest average 354.3 mg/L in mid-monsoon which is higher than the BIS limits. The contents of HCO_3^- have no adverse health effects; however, it should not exceed the safe limits of 300 and 250 mg/L respectively, in drinking water. The results indicate the absence of hydroxide and carbonate alkalinity and presence of bicarbonates. It ranged from 19.6 to 157 in first year and 32.8 to 154 mg/L in second year. The average highest value 90.6 mg/L was observed from pre-monsoon season. It's well within the prescribed limits.

In the present study it showed well within the prescribed limit set by the BIS. The values ranged between 36.8 to 400 mg/L and 40.4 to 383.1 mg/L in both consecutive years. The average concentration was 215.8 in pre-monsoon season. Chloride(Cl^-) in ground and surface water from both natural and anthropogenic sources such as run-off containing deicing salt, the use of inorganic fertilizers, landfill leaches, septic tank, effluents, animal feeds and irrigation drainage (Ottawa, 1978).

Nitrate (NO_3-N) nitrate value is considered relatively non toxic. Nitrate value may be reduced by microbial degradation. During the study period none of the groundwater samples were exceeded the nitrate limits set by the BIS. The average nitrate range was recorded 0.04 mg/L in various seasons while highest value was recorded 0.34 mg/L from mid-monsoon 2010-11 and least was nil in post-monsoon 2011-12.

Phosphate (PO_4-P) values were lower in groundwater samples during all the three seasons due to contributions from phosphate minerals such as apatite and fluor-apatite and also from mobilization of phosphate. The values of phosphate ranging between 0.03 to 0.2 mg/L in the year 2010-11 and nil to 0.2 mg/L in 2011-12. The less phosphate values indicate that the water of these wards was not polluted with anthropogenic loads.

Table 2: Statistical summary of average of groundwater samples analyzed from different wards of BMC during the study period (2010-2011)

	BIS (2012)	Pre-monsoon 2010-11			Mid-monsoon 2010-11			Post-monsoon 2010-11		
		Max	Min	Average	Max	Min	Average	Max	Min	Average
Water Temp		30	20	26.8	27.2	20	24.3	22.8	15	19.8
pH	6.5-8.5	8	6.8	7.3	8.4	7	7.4	8.0	6.9	7.4
EC	2000	7452	156.4	1618.5	3356.6	249.9	1499.1	2620	311	1421.5
TDS	500	1798.8	256.6	923.5	1347.4	286.4	898.6	1730	177.8	936.5
TH	200	1164	101	339.3	1075	188	354.3	1087	199.6	344
Cl^-	1000	351.1	36.8	176.1	400	41.6	171.8	417.5	36.8	159
$HCO3^-$	--	152.0	32.8	89.7	157	19.6	86.8	146.0	25.2	87.3
$NO3^-N$	45	0.1	0.02	0.03	0.34	0.02	0.04	0.11	0.02	0.04
$PO4^-P$	--	0.2	0.03	0.05	0.2	0.03	0.04	0.2	0.03	0.05
F^-	1.0	2.4.	0.07	0.5	1.9	0.07	0.43	1.9	0.07	0.5

Table 3: Statistical summary of average of groundwater samples analyzed from different wards of BMC during the study period (2011-2012)

	BIS (2012)	Pre-monsoon 2011-12			Mid-monsoon 2011-12			Post-monsoon 2011-12		
		Max	Min	Average	Max	Min	Average	Max	Min	Average
Water Temp		29.4	19.6	25.7	28.2	18.8	24.9	26.4	17	22
pH	6.5-8.5	8.1	7	7.3	8.1	7	7.4	8.1	7.1	7.4
EC	2000	2490	335.2	1434.5	3317.6	272.8	1456.3	2533.1	337	1432.8
TDS	500	1580.2	120.2	832.9	1343.2	118.2	787.2	1428	1300	789.7
TH	200	521.8	101	320.5	1065.2	206.8	349.2	1084.6	201.2	351.2
Cl^-	1000	219.8	40.4	215.8	383.1	54.6	166.3	373.6	46.3	158.2
$HCO3^-$	--	154	32.8	90.6	146.0	40.6	87.4	135.0	41.0	88.4
$NO3^-N$	45	0.3	0.02	0.04	0.3	0.02	0.04	0.1	0.0	0.0
$PO4^-P$	--	0.2	0.03	0.05	0.2	0.03	0.04	0.2	0.0	0.0
F^-	1.0	2.4	0.1	0.5	5.65	0.11	0.5	2.28	0.1	0.4

*All parameters are expressed in mg/l expect Temperature (°C), PH and EC (µs)

Fluoride (F) concentration in the study area is depicted in Table -2 and -3. The present study was undertaken the physico-chemical characteristics including fluoride in the drinking water of Bhagalpur Municipal corporation area, Bhagalpur district (Bihar, India) between 2010-12. Out of 51 wards, 12 wards are located far from the river Ganga are affected with excess fluoride (>1.5 ppm) in most of the wards (39-51). The fluoride concentration in the groundwater samples shows a define trend with respect to the area of sampling (Figure 2). The fluoride content was fluctuating with the variation in rainfall and water table. Recent report stated that the groundwater as contagion has extended to 16 districts, intimidating more than 10 million people in Bihar (Gosh *et al*., 2009; Saha 2009; SOES, 2012).

In the present study, in groundwater low or high concentration fluoride depends upon the rock and fluoride baring minerals. High fluoride concentration may be expected in groundwater from the aquifers where fluoride bearing minerals are common. All the data on fluoride was digitized with the help of GPS points and averaged value of fluoride was used for kriging in Q-GIS software (Ver.-3.18). The results clearly revealed that the high level of fluoride contamination in southern wards. The river Ganga plays a vital role in groundwater recharge and neutralizing the geogenic fluoride in deep aquifers of BMC. But in case of ward number 26 and 27 which is close to river Ganga showed exceptional case. The population density and sanitation also found to be one of the causes of fluoride contamination in southern wards from 39-51.

To enhance the knowledge on fluoride effects on health hazards, all the wards were surveyed at the time of water sample collection. The sample size was restricted to n=100 for each ward to make uniformity. The data on fluorosis was interpolated on kriging based maps of fluoride of BMC and found that the daily uses and regular consumption from long term of contaminated water has given negative effect on the health of people residing in theses wards. Most of the wards were affected with at least dental fluorosis but as the concentration increases the severity of disease also increased. Very significant correlation was observed

through interpolation map of BMC, Bhagalpur (Figure 2). Consequently the BIS limits of drinking water permits to attain imperative information on health hazards due to Fluoride Contamination in BMC Area, Bhagalpur situated on the bank of the river Ganga. This city has listed in 100 smart cities all over the nation but still most of the population fulfills their need for drinking water from these contaminated groundwater sources.

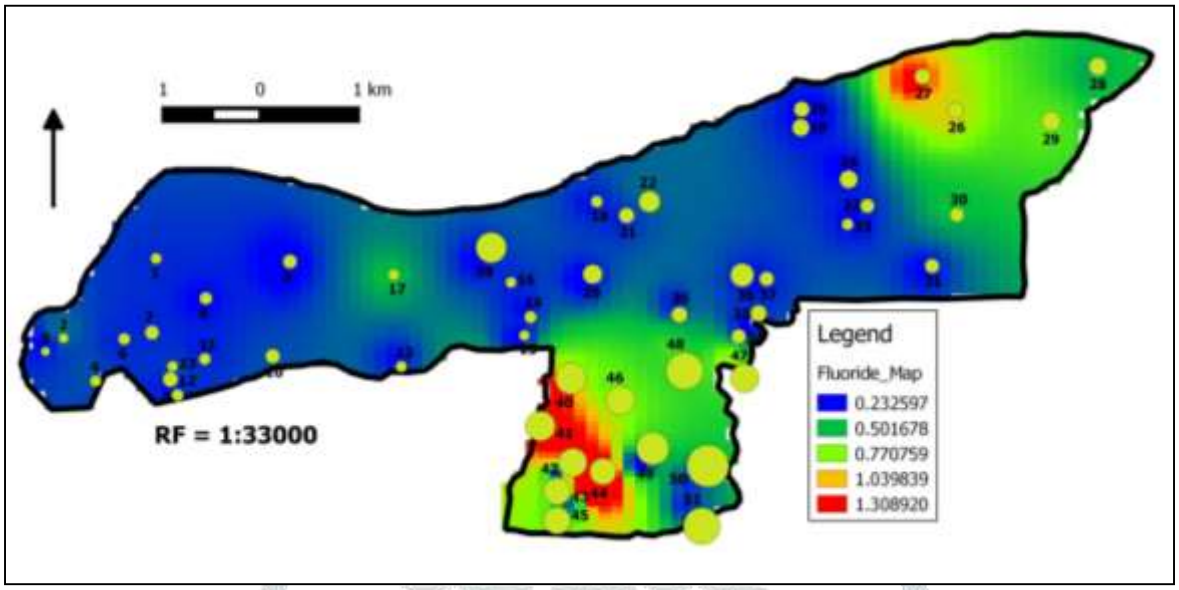

Figure 2: GIS based kriging and interpolation map of fluoride and associated disease (Fluorosis) in wards of BMC, Bhagalpur during 2010-12

V. CONCLUSION

Assumption on quality drinking water is important for present and future water management consequently. The canalization of irrigation water quality plays an important role in improving its management strategies for drinking purposes. The improper managements of water system may cause serious problem in availability and quality of water in near future (Kendaraganna 2000; FAO 2003) and create risk especially for children and female group. Developing the alternate sources will consensus of Bhagalpur Municipal Corporation will result in better conservation, development and management of groundwater consumption for the residents. Therefore, it is important to study the quality of drinking water, contaminants and improved supply system furthermore in detail to obligate for human well being.

VI. ACKNOWLEDGEMENT

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