Research Article

Evaluating Fluoride Contamination in Groundwater of Barmer District, Rajasthan by GIS

Archana Singh[1]*, Anurika Mehta[2], and Rakesh Duggal[1]

[1]Department of Chemistry, Poornima Group of Institutions, Jaipur, India
[2]Department of Chemistry, Poornima Institute of Engineering and Technology, Jaipur, India

Abstract
Fluoride concentration study in groundwater of some rural areas of Barmer district, Rajasthan has been carried out using GIS because these areas do not get centrally treated water to fulfill their needs of drinking water and are totally dependent on untreated groundwater. As a result, there are many diseases prevalent in this area. The area under study has rocky formations with abundance in fluoride minerals and at the same time overexploitation of groundwater is being done to fulfill drinking needs of people. Fluoride concentration varies from 0.6 mg/L to 20.10 mg/L for 30 water samples collected from different areas of Barmer district, Rajasthan for identifying the fluoride contaminated areas by GIS analysis. On this basis, study areas are divided into safe and unsafe zones and high fluoride contaminated zones require urgent remedial action for providing safe drinking water.

Keywords: Fluoride concentration, Safe drinking water, Groundwater contamination, GIS.

***Correspondence**
Author: Archana Singh
Email: archanasingh@poornima.org

Introduction

Fluorine has double edged effect on human beings as deficiency as well as its excess is detrimental in causing diseases and thereby adding to human sufferings. The main source of fluoride in groundwater are calcium fluorite (CaF_2), fluorapatile [$Ca_5 (PO_4)_3F$] and cryolite (Na_3AlF_6) [1]. Fluoride in drinking water is in an ionic form and hence rapidly passes through the intestinal mucosa and interferes with metabolic activities of the living system. Upward adjustment of fluoride in water supplies to the extent of 1.0 mg/L results in considerable reduction in the incidences of dental caries [2] but higher concentration is responsible for dental and skeletal fluorosis, osteoporosis, arthritis, hip fracture, mental retardation while low concentration (below 0.5mg/L) causes dental caries [3, 4].

The quality of groundwater is greatly affected by many factors like industrialization, urbanization, irrigation activities etc. So regular monitoring of groundwater is necessary and, therefore, study focuses on occurrence of fluoride concentration in groundwater of some villages of Barmer district, Rajasthan.

Experimental

Study Area

The total area of Barmer district is 28,387 square kilometers (10,960 sq m) and population is 12,603,751 and is located between 24.58' to 26.32' N latitudes and 70.05' to 72.52' E longitudes. The seasonal variation in temperature is quite high. In summers, the temperature soars to 46°C to 51°Cwhile in winters it drops to 0°C. Average rainfall in a year is 277 mm. **Figure 1** represents Barmer district.

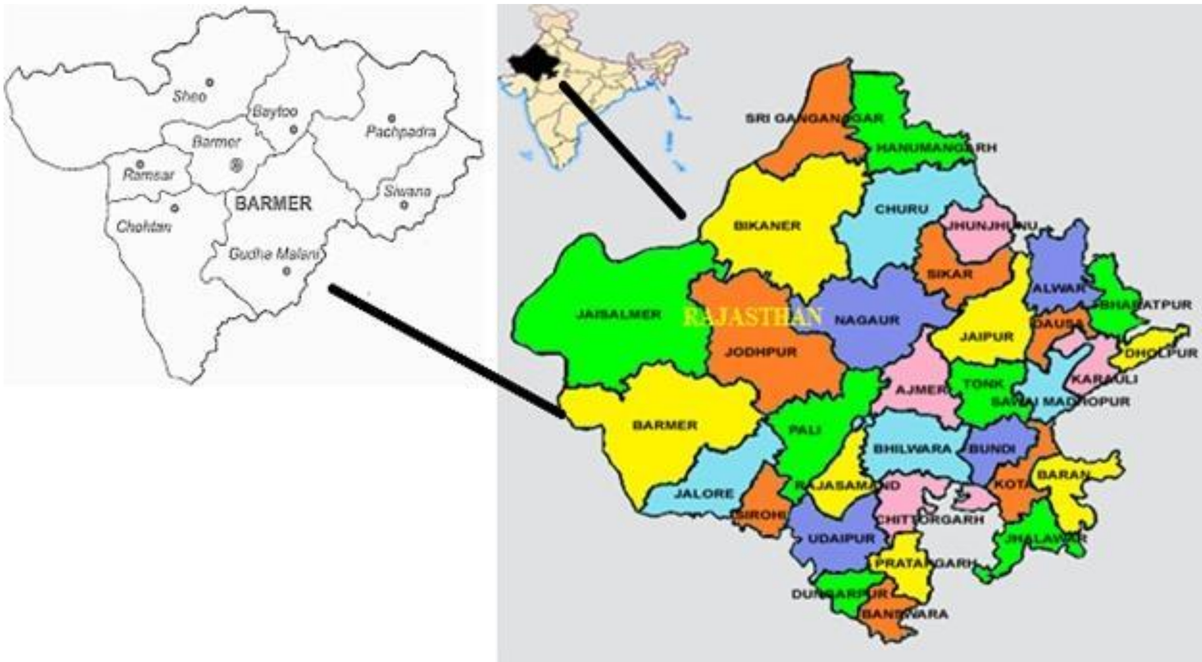

Figure 1 Map of study area

Geomorphology [5]

Geographically, the area as a whole forms a part of the Great Indian Desert. Apart from a small offshoot of the Aravalli hills in the east, the area is a vast sandy track. The country west of Luni River represents sandy plain dotted with bold hills. A well-defined valley is observed along Barmer-Gadra road to the east of Kharin. Pachpadra, Sanwarla and Thob are the major salt lakes in the district. A Salt Lake locally called Rann is located east of Redana village. The surface elevation of the district varies from 70 above mean sea level (mamsl) at Sindhari to 457 mamsl at Ghonia village. The only major drainage course in the area is Luni River, which flows from Samdari, passing through Balotra. The river is ephemeral, flowing only in response to heavy precipitation and there is no run off during draught.

Hydrogeology [5]

The main water bearing formations in the district are rhyolites and granites of post Delhi; Lathi sandstone, Tertiary sandstone and Quaternary alluvium. In Quaternary alluvium, ground water occurs under semi confined to unconfined conditions. In semi consolidated Tertiary and Mesozoic formations, it occurs under unconfined to confined conditions and in weathered and fractured zones in hard rocks under phreatic conditions. Though ground water occurs in all the formations but the most productive aquifers are the Lathi sandstone, Barmer sandstone and Quaternary sediments. The Tertiary formation, which is predominantly clayey and argillaceous, is not found as productive except locally in the sandstone horizon. In general, the fractured and weathered zones in hard rocks form poor aquifers. Consolidated formations include intrusive of Malani rhyolite and granite.

Materials and Methods

Total 30 groundwater samples were collected from tube wells of different villages of Barmer district as per standard norms and sampling sites are shown as S1 to S30 in **Figure 2**.

The analysis for fluoride in groundwater samples was carried out as per APHA standard methods [6]. The SPADNS method has been used for determining the concentration of fluoride in groundwater samples (**Table 1**). GIS (geographical information system) was used for analysis of fluoride distribution in different areas and areas have been divided into safe or unsafe zones on the basis of fluoride contamination. The present study shows lower and higher permissible limit of fluoride concentration in groundwater as 0.5 mg/L and 1.5 mg/L respectively as per water quality standard adopted by Bureau of Indian Standards [7].

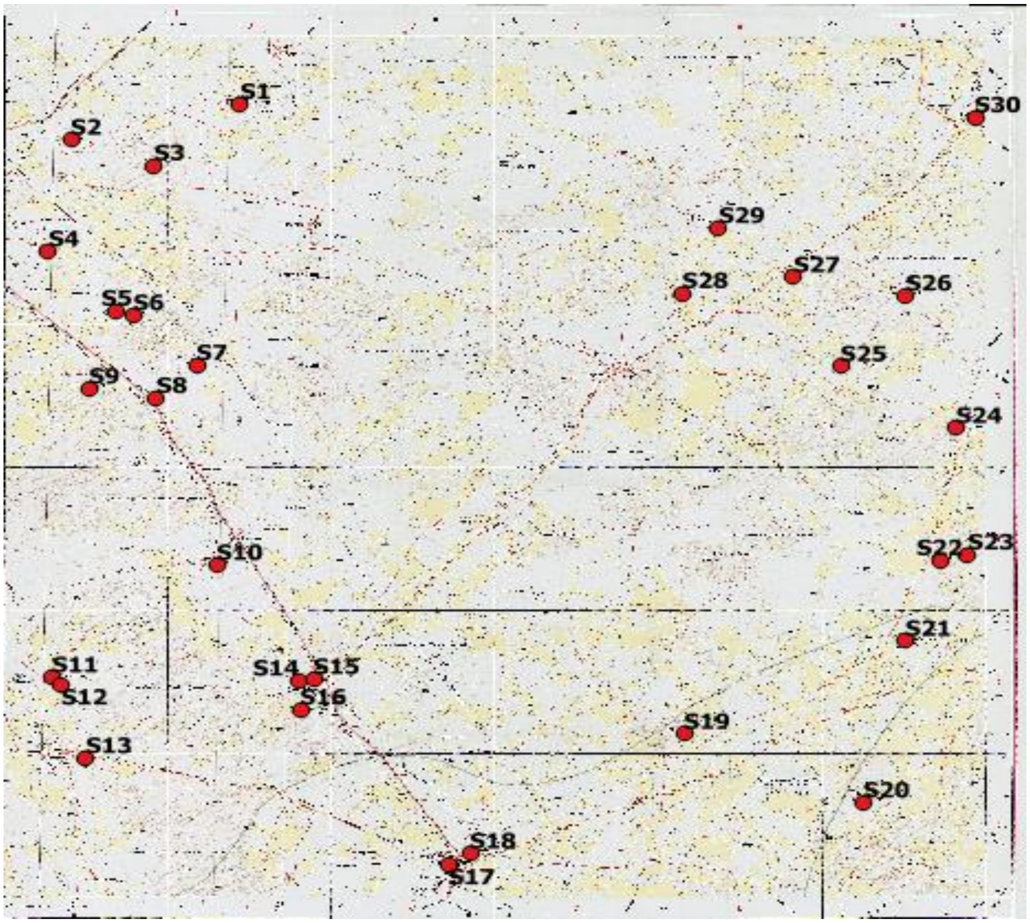

Figure 2 Map of study area with sampling sites

Table 1 Fluoride concentrations in different groundwater samples of study area

Sample No.	Location	F^- (mg/L)	Sample No.	Location	F^- (mg/L)
S1	Rato Bhakhar	0.8	S16	Chataliya Thali	1.6
S2	Balai	1.4	S17	Bharka	20.1
S3	Dukri Thali	1.4	S18	Bharka	17.6
S4	Kotariya ki Dhani	1.4	S19	EKG Dhora	0.7
S5	Banakiya Dhora	1.2	S20	Mulji ka Tala	0.6
S6	Banakiya Dhora	1.4	S21	Megasar Tala	0.7
S7	Nimbasar	0.6	S22	Rohirewali Nadi	0.8
S8	Diggi	10.05	S23	Rohirewali Nadi	0.7
S9	Jadeli ka Dhora	0.7	S24	Posal	0.7
S10	Agoriya	1.5	S25	Shakur Khan ki Dhani	1.5
S11	Giral	2.1	S26	Posal Talai	1.5
S12	Girel	1.2	S27	Posal Talai	1.6
S13	Thumbli	20.1	S28	Kumharon ki Dhani	10.05
S14	Nimbla	15.5	S29	Nimla Talai	20.1
S15	Nimbla	20.1	S30	Mokhab	3.3

GIS Modeling

GIS mapping was done by using software QGIS version 2.6. A geographic information system provides an abstract model of the real world, stored and maintained in a computerized system of files and databases in such a way as to collection, creation, facilitate recording, management, analysis and reporting of information as shown in **Figure 3**.

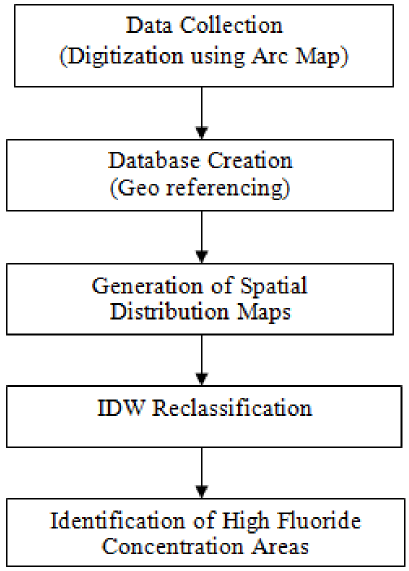

Figure 3 Methodology flow chart for GIS study

Results and Discussion

On the basis of above values of fluoride concentrations, it can be concluded that many villages of district have higher fluoride concentration than permissible limit. Maximum fluoride concentrations have been found in Diggi, Thumbli, Nimbla, Bharka, Kumharon ki Dhani and Nimla Talai villages. Fluoride concentrations exceeding 2.5 mg/L in the drinking water appear to be critical for manifestation of severe forms of skeletal fluorosis [8]. Correlation of diseases due to abundance of fluoride content is shown in **Table 2** [9]. It can easily be correlated that people of sample locations S8, S13, S14, S15, S17, S18, S28 and S29 suffer from neck bone pain and back pain and also with crippling fluorosis due to very high concentration of fluoride in groundwater of these areas. Some areas with sampling sites S11, S16, S27 and S30 have been found with people suffering from dental fluorosis due to upper range of fluoride 1.6 mg/L to 4.0 mg/L. Remaining study areas [S1, S2, S3, S4, S5, S6, S7, S9, S10, S12, S19, S20, S21, S22, S23, S24, S25 & S26] with permissible limit of 0.5 mg/L to 1.5 mg/L fluoride concentration 0.1 mg/L to 0.5 mg/L were not affected by diseases due to deficiency of fluoride. Thus, it appears that areas represented by sampling sites S8, S11, S13, S14, S15, S16, S17, S18, S28, S29 and S30 are real areas of concern for ensuring potable water within permissible limits of fluoride concentration and need immediate remedial action.

Table 2 Concentration of Fluoride in samples

S. No	Categories	Fluoride Concentration (mg/L)	Effect on human health	Representing Samples	Percentages
1	Low	0.1-0.5	Dental caries	-	0%
2	Permissible	0.5-1.5	Prevents tooth decay	S1,S2,S3,S4,S5,S6, S7,S9,S10,S12,S19, S20,S21,S22,S23,S24, S25,S26	60.00%
3	High	1.5-4.0	Dental fluorosis	S11,S16,S27,S30	13.33%
4	Very High	>4.0	Pain in neck bones and back and crippling fluorosis	S8,S13,S14,S15,S17, S18,S28,S29	26.67%

From pie graph analysis it can be concluded that only 60% groundwater samples are within the permissible range and thus fall in category of drinking water whereas 40% groundwater samples cannot be used for drinking purposes because of high or very high concentration of fluoride as shown in **Figure 4**. So many fluoride treatment methods like defluoridation are required before providing groundwater for drinking purposes for these areas.

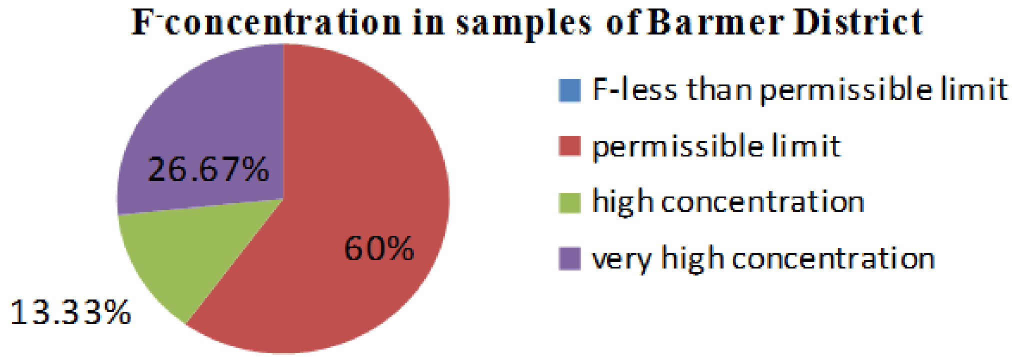

Figure 4 Pie graph representing the fluoride contamination in different samples of Barmer district

GIS Mapping

It can be broadly stated that a geographic information system consists of a set of software, hardware, processes and organization that integrates the value of spatial data. The different locations of the sampling stations were imported into GIS software through point layer. The geo-database was used to generate the spatial distribution map of selected groundwater quality parameter which is fluoride. GIS is gaining importance and widespread acceptance as a tool for decision making or support in the infrastructure, water resources, environmental management, spatial analysis and urban regional development planning. With the development of GIS, environmental and natural resources management have found the systems in which data are more readily accessible, more easily combined and modified to meet the needs of environmental and natural resources decision making. In this study, GIS is extensively used to identify the zones of suitable and alarming stage of groundwater quality in the different villages of Barmer district based on the sampled data.

Figure 5 provides interpolation map of fluoride concentration, in which very high concentration was found in south-west with sample numbers S13, S14, S15, S16, S17 and S18 and central part with sample numbers S28 and S29 of study area. High fluoride concentration was shown by in and around the above sample numbers with red colour and green colour areas shown fluoride concentration was in permissible limit.

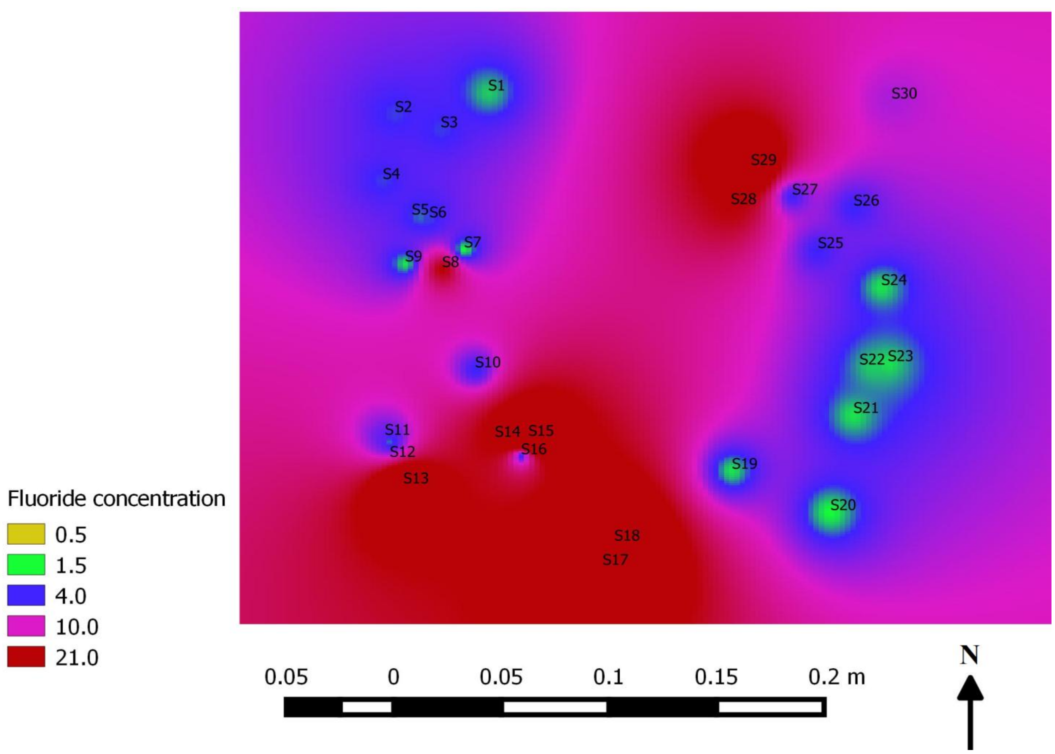

Figure 5 Interpolation map of Fluoride concentration of study area

Contour map of fluoride concentration in different villages of Barmer district is represented in **Figure 6**. Fluoride concentration was shown with orange color and the sample location was indicated with black color. The predicted values were also shown to be high in and around south-west part and shown with red color.

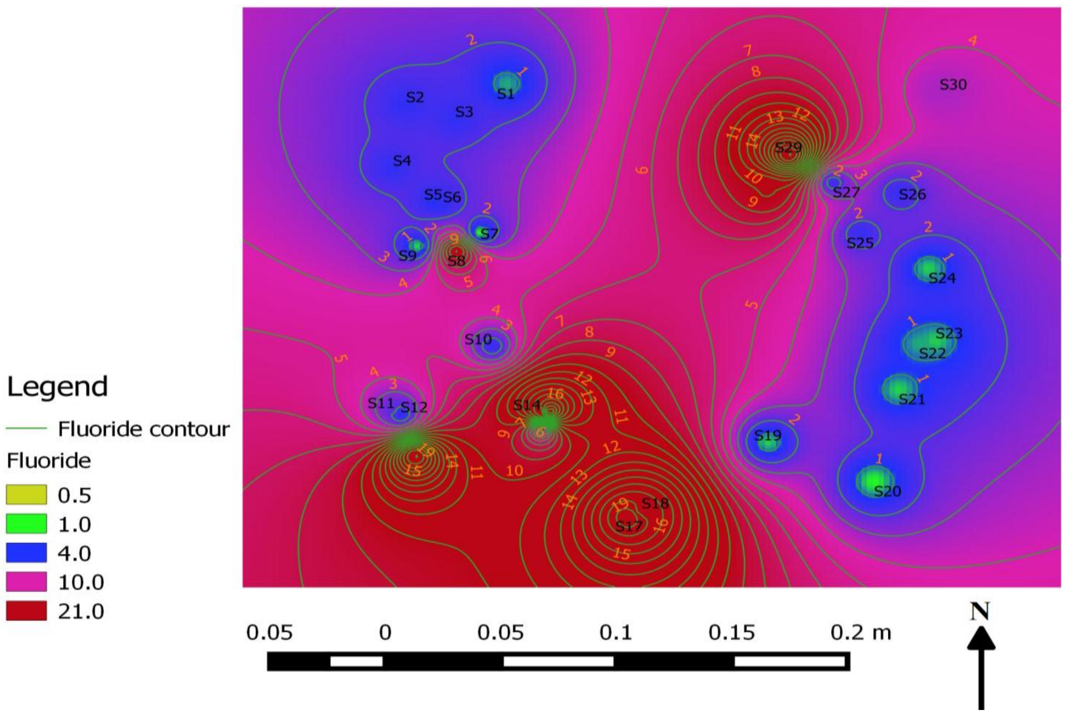

Figure 6 Contour map of Fluoride concentration of study area

Conclusions

The study provides an overview of the fluoride concentration in drinking water and points health hazards in these areas of Barmer district due to higher fluoride content. The responsible factor which contributes to rise of fluoride in groundwater is the presence of fluoride rich rock salt system and gravel waste in the area of study. The samples collected from south-west and central part of Barmer were more contaminated with fluoride due to low dilution and low dilution tends to the accumulation of fluoride ions. It is desirable that potable water be provided to these rural areas and the results of current study as well as other available data should be taken into account to ensure quality of groundwater in minimum possible time so as to ensure safe drinking water in the area. In a nut-shell, immediate remedial action is needed to safeguard the health of people of these areas and surroundings of selected study area of Barmer district, Rajasthan.

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