DISTRIBUTION AND CONCENTRATION OF FLUORIDE IN NAGAUR DISTRICT, RAJASTHAN

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Abstract

Water is the basis of origin of living species and is essential for survival of life on this planet. From a health point of view, fluoride is an important ion for all living entities. It helps with natural bone mineralization and dental enamel formation. The human body absorbs fluoride quickly, but slowly excretes it (Shen et al., 2016; Sun et al., 2016). In drinking water, the recommended fluoride concentration is 1.5 mg/L (WHO, 1984). It is commonly thought that "too little (< 0.5mg/L) or too much (> 1.5mg/L)" will affect the structure of the bone and teeth with regard to drinking water. Fluoride, however, is harmful to human health at concentrations beyond 1.5 mg/L, leading to skeletal and dental fluorosis disorder that can cause subtle shading of the teeth, tendon inflammation, debilitating bone deformities, and many other chronic diseases that can eventually lead to death. It is therefore important to have a healthy fluoride ion concentration limit in drinking water of between 0.6 and 1.2 mg/L (ISI, 1983). The fluoride concentration level is set between about 1.0 and 1.5 mg/L by the Indian standards (BIS). The hydrology of the region, geological nature of underlying rocks and differential soil formation processes are the prime factors responsible for this uneven distribution of fluoride in groundwater in different parts of the Nagaur district.

Keywords: Essential, Survival, Fluoride, Concentration, Harmful, Disease, Dental and Skeletal Fluorosis.

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Introduction

On the basis of prevalent scientific research and government reports, a very high level of fluoride contamination is reported to be found in most of the water sources such as hand pumps and bore wells, situated in rural parts of the state. Therefore, dependence on these sources for drinking water is not very safe for both human and animal health. The fluoride level in these sources is found much more than both countries' standard limit of 1.0 ppm (mg/L) set by BIS as well as WHO maximum limit of 1.5 ppm (mg/L) has allowed in case there is no alternate source of drinking water available. Moreover, according to Bureau of Indian Standards lesser the fluoride the better, as fluoride is injurious to health. In 2003, the specifications for Indian Standard drinking Water were revised to include the term "desirable limit" in parentheses after the word "requirement". Then, in 2012, the septic requirement for the maximum limit of 1 ppm (mg/L) was again revised to the replace the expression "desirable limit" with "acceptable limit".

Objectives of the study

- To explore the fluoride distribution in the groundwater of Nagaur district, Rajasthan, India.
- To prepare fluoride distribution maps of Nagaur district by using GIS Technique.

Data sources

The present study has been completed based on both primary and secondary sources. Official documents and reports are the major primary sources and secondary sources collected from Books, Journals, Articles, Newspapers, and Electronic sources. Data related to fluoride concentration in groundwater and health obtained from Census of India (2001, 2011); Meteorological Department of India; Central Ground Water Board (2013), Government of India, Ministry of Water Resources; Public Health Engineering Department(1993, 2011); Hydrological Atlas of Rajasthan, Nagaur District; Rajiv Gandhi National Drinking Water Mission, 1986; 1993), and Revenue department.

Research methodology

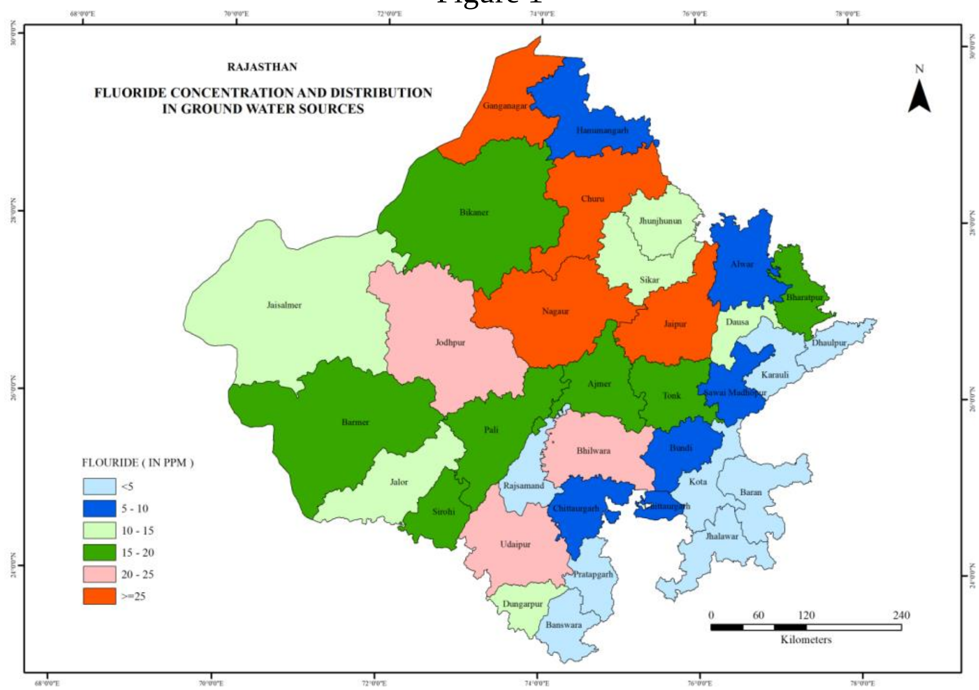
A methodology is a way to proceed in research work. It is a pre-defined path to achieve specific goals. The detailed evaluation and analysis of data have been discussed in this study. The processed data has been presented cartographically or in tabular form. Graphical representation was done to enhance the merit of the research. The maps presented in the study were prepared by Interpolation (Inverse Distance Weighting, IDW) technique in GIS software to get more clarity and accuracy in the presentation of data. The graphical presentation of data was made through MS-Excel. The study is based on an explanation and evaluation of data, which detailed how groundwater has fluoride concentration in the Nagaur district

Analysis and discussion

It may be said that the review of literature indicated the Prevalence of fluoride content in the water has a disastrous impact on the health of the human population, livestock, and crops in the studied area. It is now pleasing to test the diverse domestic defluoridation processes, mainly in terms of receiving by people without the need of any supervising agency, and urge appropriate alternatives in order that efficient long term implementation can be achieved.

Recently, concentration of fluoride ions in groundwater sources in all districts of the state were studied and analysed. The maximum concentration of fluoride ions in groundwater and drinking water was recorded in Nagaur district (90.0 ppm) "followed by Churu (32.0 ppm), Sri Ganganagar (28.2 ppm), Jaipur (28.1 ppm), Bhilwara (24.0 ppm), Jodhpur (22.0 ppm), Udaipur (21.6 ppm), Bikaner (20.0 ppm), Barmer (19.6 ppm), Bharatpur (18.4 ppm), Pali (18.3 ppm), Ajmer (17.6 ppm), Sirohi (16.0 ppm), Tonk (15.8 ppm), Sikar (15.0 ppm), Dausa (14.9 ppm), Jalore (14.2 ppm), Jaisalmer (12.0 ppm), Jhunjhunu (12.0 ppm), Dungarpur (10.8 ppm), Sawai Madhopur (10.0 ppm), Alwar (9.9 ppm), Hanumangarh (8.5 ppm), Bundi (6.8 ppm), Chittorgarh (6.6 ppm), Dholpur (4.9 ppm), Kota (4.8 ppm), Pratapgarh (4.7 ppm), Banswara (4.6 ppm), Karauli (4.5 ppm), Rajsamand (4.5 ppm), Baran (2.0 ppm), and Jhalawar (1.5 ppm) district" (Figure 1) (Choubisa 2018).

Figure 1



Factors responsible for concentration and distribution of fluoride in groundwater in nagaur district

The most significant factor which is responsible for increased levels of fluoride concentration in groundwater sources is the existence of underlying fluoride and phosphate rich rocks and minerals. The leaching and accumulation of fluoride ions in soil horizons and groundwater takes place through weathered rocks, rainfall and from fertilisers and surface run off. Drinking water is the largest contributor to the daily fluoride intake. The food when derived from plants grown in the contaminated soil also becomes another source of fluoride intake (Perumal et al., 2013). Increases in number of incidences of dental and skeletal fluorosis have occurred due to increased levels of fluoride concentration in drinking water sources (Hussain et al., 2012). Table 1 shows the sources of fluoride in groundwater.

Table 1 Sources of Fluoride In Groundwater

Minerals	**Rocks of these minerals**
Fluorite (Fluorspar)	Pegmatite Pneumatolitic deposits as vein deposit
Flurapatite (Apatite)	Pegmatite & metamorphosed limestone
Mica Biotite Muscovite	Basalts Permatites, Amphiboites
Amphiboles Hornblende Tremolite Actinolite	Gneisses, schists, shales, Clay Aklaline rocks etc
Topaz	Acid, Igneous rocks, schists, gneisses etc
Rock Phosphate	Limestone, fossils etc

Source: (Dissanayake C.1991)

In Rajasthan, the unusual high levels of fluoride content in groundwater sources in all the district is a natural occurrence of fluoride and not anthropogenic. This is primarily due to geological and hydrological features of rocks and sediments in the region. The average amount of fluoride ions in different rocks and sediments varies within the range of 180 ppm and 31000 ppm. The most common fluoride containing mineral and rocks found in the region include alluvium, granite, basalt, gneiss, clays, mica, sandstone, shale, limestone, phosphorite and schist. Chemical properties of these rocks such as dissolution, decomposition and dissociation are known to be principal cause for concentration of fluoride ions in groundwater. Apart from geological features, regional differences in concentration and distribution of fluoride are determined by climatic variations, regional physiography and hydrological conditions (Choubisa 2018). Also, aquifers found at greater depths are considered more favourable for higher fluoride concentration in water due to slow movement of groundwater (Saxena and Ahmed 2001; 2003). According to Handa (1975), "the genesis of high fluoride levels in groundwater in India is generally associated with low calcium content, there being a negative correlation between the two ions, causing low solubility of fluorite". In Rajasthan, occurrence of fluoride is generally found in the form of calcium fluoride (CaF2), also known as fluorspar; cryolite (Na3AlF6) and; Phosphorite i.e rock phosphate. Among different rocks, the maximum concentration of fluoride ions is found in alkaline rocks, varying within the range of 1200 mg/kg to 8500 mg/kg. While granite has higher levels of fluoride content, as much as five times greater than fluoride content found in basaltic rocks, sedimentary rocks such as limestone and sandstone has lower fluoride concentration in comparison to metamorphic (e.g shale) and igneous (e.g. basalt and granite) rocks. The varying level of fluoride content in different rocks is shown in Table 2.

Table 2 Value of Fluoride in Various Rock Types

Rocks	**Flouride range (in ppm)**	**Average (in ppm)**
Basalts	20-1060	360
Granites and Gnisses	20-2700	870
Shales and Clays	10-2700	800
Limeatones	0-1200	220
Sandstones	10-880	180
Phosphorite	2400-41500	31000
Coal (ash)	40-480	80

Source: (Dissanayake, C.1991)

Though concentration of F ions in groundwater is largely due to geological and hydrological factors, but there are some man-made factors also which has contributed in further enhancing the accumulation and concentration of fluoride in natural environment to a very great extent. Various human activities such as unregulated discharge from manufacturing industries, rock and mineral mining, use of pesticides and fertilizers in agricultural fields leads to release of pollutants such as nitrates, organics, cyanide, heavy metals and aluminium in surrounding environment, thus, causing higher levels of accumulation of fluoride ions in groundwater sources (Rao 2012; Pettenati et al. 2013). Use of fluoride contaminated water for irrigation purpose also contributes in adding more fluoride to the groundwater (Pettenati et al., 2013).

Climatic factors are other significant determinants of levels of fluoride concentration in natural environment (Rao 2012). For instance, under dry climatic conditions, high rate of evaporation causes higher deposition and accumulation of fluorine in water (Weinstein and Davidson 2004).

On the contrary, in humid climatic zones, due to high amount of rainfall and greater leaching of fluoride ions, there is much lower concentration of fluoride (Edmunds and Smedley 1996). The level of fluoride concentration is much higher (more than 1.0 mg/L) in oceans and seas as compared to freshwater bodies i.e. lakes and rivers having fluoride levels less than 0.5 mg/L. The substantial level of fluoride concentration in groundwater, however, exists predominantly in areas where fluorine is present in high abundance in local sub-terranean minerals and rocks. While determining the levels of fluoride concentration in a particular surrounding, topographical characteristics also play very significant role. The dissolution of fluoride ions in groundwater is facilitated by different topographical features such as rate of evaporation, alkalinity, and levels of bicarbonate in groundwater (Tirumalesh et al 2007). It is noticeable that most of the fluroride endemic regions of the world are located in tropical and subtropical latitudes characterised by dry climatic conditions Ali et al. 2016). Furthermore, there is very high level of fluoride concentration in tropical regions as compared to temperate regions. This variation is mainly due to the fact that daily water intake by people is generally more under dry climatic conditions (Hussian et al 2013). According to the climatic classification of Koppen, "a dry tropical climate with hot summer and cold winter comes under the type of BWhw, where health issues are more likely to occur due to the high fluoride concentration accumulation in drinking water".

Groundwater Fluoride Concentration and Distribution – nagaur

Table 3 depicts block wise area of fluoride distribution in Nagaur district. The regions having moderately high fluoride concentration (1.5-3.0 mg/L) are depicted in green colour that occupies approximately 54 per cent of the total area of district and the areas falling in the category of high fluoride concentration (>3.0 mg/L) are presented in red colour which occupy 25 per cent of the district area. Together these areas account for about 79 per cent of district areas where groundwater is unsuitable for domestic purposes because of high (>1.5 mg/L) fluoride concentration. The remaining part (21 per cent) of the district area falls under low concentration (<1.5 mg/L) and is shown on the map with yellow color. Such areas are seen largely in the southern part of Ladnu and around the Kuchaman City and Nawa where the groundwater is suitable for the domestic purpose (CGWB 2013). Figure 1 depicts the fluoride concentration and distribution in groundwater sources of Nagaur district.

Table 3 Block Wise Area of Fluoride Distribution (Area and Percentage)

Fluoride concentration range (mg/L) (Avg. of Years 2005-2009)			**< 1.5**	**1.5-3.0**	**>3.0**	**Total**
Block Wise Area Coverage (sq km)	Degana	Area	98.8	844.1	635.7	1578.6
		%age	6.3	53.5	40.2	100.0
	Didwana	Area	436.0	1094.1	111.7	1641.8
		%age	26.6	66.6	6.8	100.0
	Jayal	Area	358.4	1528.1	314.7	2201.2
		%age	16.3	69.4	14.3	100.0
	Kuchaman city	Area	1220.3	338.1	67.0	1625.4
		%age	75.1	20.8	4.1	100.0
	Ladnu	Area	460.2	446.2	368.9	1275.3
		%age	36.1	35.0	28.9	100.0
	Makrana	Area	20.9	473.5	580.0	1074.4

		%age	2.0	44.0	54.0	100.0
	Merta	Area	387.7	958.2	7.7	1349.6
		%age	28.4	71.0	0.6	100.0
	Mundwa	Area	89.3	1508.9	737.3	2335.5
		%age	3.8	64.6	31.6	100.0
	Nagaur	Area	306.0	1115.6	1133.3	2554.9
		%age	12.0	43.7	44.3	100.0
	Parbatsar	Area	315.8	547.7	163.7	1027.2
		%age	30.7	53.4	15.9	100.0
	Riyan	Area	78.8	771.8	249.8	1106.7
		%age	7.0	70.0	23.0	100.0
	Total Area (sq km)		3768.2	9632.6	4369.8	17770.6

Source: Central Ground Water Board, 2013

Fluoride is one of the worst affecting health hazardous ions found in water in low concentrations. Its concentration in water ranges from 0 mg/L to 50 mg/L. various standards suggested to the standards limit. In India, according to BIS for drinking water, there are two limits for fluoride concentration viz. Maximum Desirable Limit i.e. 1.0 mg/L and Maximum Permissible Limit of 1.5 mg/l (Arif M. 2015). Data collected by M. Arif in 2015 from 466 villages related to fluoride concentration in groundwater was gathered from Rajasthan government's Public Health and Engineering department and Revenue department. The samples of water were collected, from tube wells and hand pumps either privately owned or established by the government of Rajasthan. All the villages with different levels of fluoride concentration in the study area were categorized into three groups as follows: -

A. Group I: - Fluoride concentration equal to or less than 1.5 mg/L.
B. Group II: - Fluoride concentration more than 1.5 mg/L and less than or equal to 3.0 mg/L.
C. Group III: -Fluoride concentration more than 3.0 mg/L.

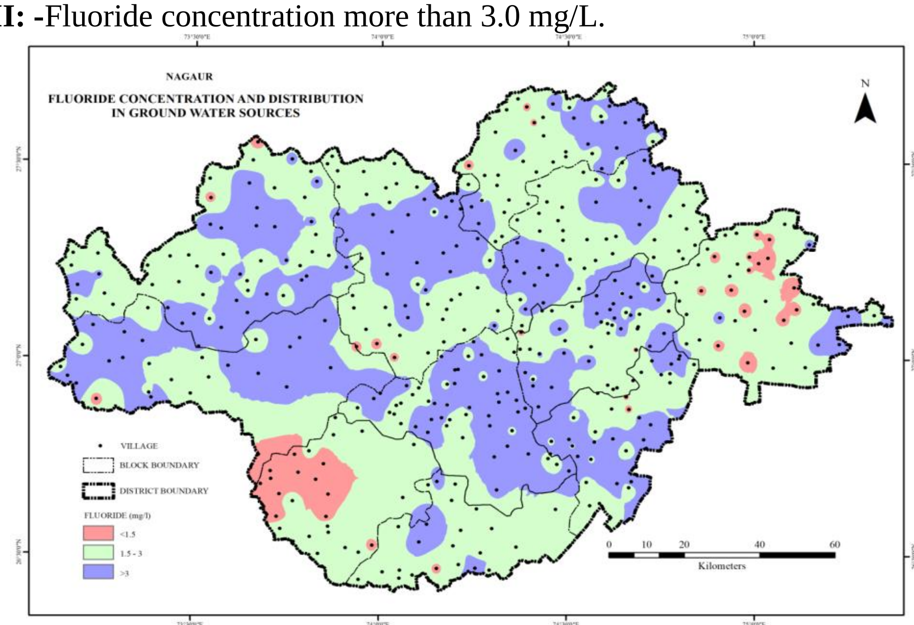


Table 4 Abstract of Fluoride Distribution in Nagaur District

S. No.	Name of Block	No. of Village Sampled	Fluoride						
			Min.	Max.	<1.0 mg/L	>1.0 but <1.5 mg/L	>1.5 but <3.0 mg/L	>3.0 but <5.0 mg/L	>5.0 mg/L
1	Ladnu	40	0.5	7.1	3	5	19	7	6
2	Didwana	54	1.1	8.5	0	8	25	8	13
3	Jayal	57	0.5	6.5	4	9	23	12	9
4	Mundwa	24	0.4	5.6	1	1	9	10	3
5	Nagaur	59	0.5	6.6	3	4	27	18	7
6	Merta	29	0.4	2.7	13	13	3	0	0
7	Riyan	23	0.5	8.5	1	8	10	2	2
8	Degana	51	1.1	14.1	0	3	21	14	13
9	Parbatsar	33	0.5	14.0	4	3	16	5	5
10	Makrana	52	0.3	8.9	7	4	17	19	5
11	Kuchaman	44	0.4	5.9	19	15	5	4	1
Total		466	Avg-0.56	Avg-8.03	55	73	175	99	64

Source: (Arif M. 2015)

Conclusion

The summary of the fluoride distribution in Nagaur district is given in Table 4. From the table, it is clear that out of 466 villages studied 338 villages have groundwater sources with high levels of fluoride concentration of more than 1.5 mg/L in which maximum contribution is from Degana Block which has 48 villages with fluoride levels more than 1.5 mg/L in groundwater. In the study maximum of 175 villages were found to have groundwater sources with fluoride levels more than 1.5 mg/L but less than 3.0 mg/L. Kuchaman and Merta blocks are least affected by high fluoride problem. They have 9 and 3 villages respectively above 1.5 mg/L fluoride. All other block has over 75 per cent of villages with fluoride higher to 1.5 mg/L. In Didwana block no village has fluoride concentration below 1.0 mg/L whereas it has a total of 13 villages having fluoride levels more than 5.0 mg/L. Nagaur Block is second most fluoride problematic block. It has a maximum of 18 villages with fluoride above 3.0 mg/L but below 5.0 mg/L.

Further, on the basis of this study undertaken, the following concluding remarks can be made that the level of fluoride concentration in groundwater in Nagaur district exceed the upper limit acceptable for human consumption as per BIS and WHO standards. Literature suggest that there is abundance of fluoride bearing rocks in the study area, consequently, leaching of fluoride takes place which results in the contamination of nearby water and soil resources. The study shows that almost all parts of the district are severely affected by high fluoride concentration. A high concentration of fluoride ions in groundwater up to 14 mg/L is found at some places in Nagaur district while the permissible limit is only 1.5 mg/L as per BIS. Highest levels of fluoride concentration are reported in Degana (14.1 mg/L), Parbatsar (14.0 mg/L), Makrana (8.9 mg/L) and Didwana (8.5 mg/L), whereas Merta (2.7 mg/L) has the lowest level of concentration followed by Mundwa (5.6 mg/L) and Kuchaman (5.9 mg/L). Thus, it can be clearly concluded that while there is uneven distribution of fluoride concentration across the different blocks and villages in Nagaur district, this difference is just relative because all the blocks suffer from high fluoride concentration in groundwater which is much more than the prescribed acceptable limit of 1.5 mg/L. Only 128 villages out of total 466 villages 'samples for the purpose are found to have fluoride concentration less than the acceptable level of 1.5 mg/L as per BIS standards.

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