Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 12(X), 2023:
http://dx.doi.org/10.7770/safer-V12N1-art2610

Scourge of high fluoride in groundwater; its implication on human health and mitigation strategies: a case study of Sikar district, Rajasthan, India.

Golpe de alto contenido de fluoruro en las aguas subterráneas; su implicación en la salud humana y las estrategias de mitigación: un estudio de caso del distrito de Sikar, Rajasthan, India.

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ABSTRACT

Water is a crucial natural resource for sustaining life and the environment but over the last few decades, the water quality is deteriorating due to its overexploitation. Fluoride is one of the critical chemical parameters, which impacts the quality of groundwater. Excess ingestion of fluoride (F) through drinking water causes 'Fluorosis' on human beings in many states of India, including Rajasthan. Sikar district in Rajasthan is also such a region where a high concentration of fluoride is present in groundwater. Due to the unavailability of surface water in Sikar district, groundwater plays an important role for all uses particularly as a drinking water source. The study was carried out to assess the fluoride contamination status and to understand its spatial variation. The fluoride concentration in groundwater of this region ranged from 0.1 to 9.94 mg/l. Physicochemical settings like decomposition, dissociation and subsequent dissolution with long residence time are responsible for leaching of fluoride into the groundwater. Artificial recharge structures are proposed to minimize the stress on groundwater extraction from deeper aquifers that are discharging fluoride in the area. There is an instant need to take urgent steps in this region to prevent the population from fluorosis.

Keywords: Groundwater, Fluoride, Fluorosis, Sikar District.

RESUMEN

El agua es un recurso natural fundamental para el mantenimiento de la vida y el medio ambiente, pero en las últimas décadas, la calidad del agua se está deteriorando debido a su sobreexplotación. El fluoruro es uno de los parámetros químicos críticos, que afecta la calidad del agua subterránea. La ingestión excesiva de fluoruro (F) a través del agua potable causa 'fluorosis' en los seres humanos en muchos estados de la India, incluido Rajasthan. El distrito de Sikar en Rajasthan también es una región donde hay una alta concentración de fluoruro en las aguas subterráneas. Debido a la falta de disponibilidad de agua superficial en el distrito de Sikar, el agua subterránea juega un papel importante para todos los usos, particularmente como fuente de agua potable. El estudio se llevó a cabo para evaluar el estado de contaminación por fluoruro y comprender su variación espacial. La concentración de fluoruro en las aguas subterráneas de esta región osciló entre 0,1 y 9,94 mg/l. Los entornos fisicoquímicos como la descomposición, la disociación y la disolución posterior con un tiempo de residencia prolongado son responsables de la lixiviación de fluoruro en las aguas subterráneas. Se proponen estructuras de recarga artificial para minimizar el estrés sobre la extracción de agua subterránea de acuíferos más profundos que descargan fluoruro en el área. Hay una necesidad inmediata de tomar medidas urgentes en esta región para prevenir la fluorosis en la población.

Palabras clave: agua subterránea, fluoruro, fluorosis, distrito de Sikar.

INTRODUCTION

Groundwater is the major and important source of drinking water on earth. The excessive and improper use, overexploitation and unwise use of groundwater have depleted groundwater availability, and also made it's quality inferior and scarce (Srinivasa et al., 2015). Groundwater containing dissolved chemicals and ions beyond the permissible limit is harmful and not suitable for domestic use. Fluoride beyond desirable extents (0.6 to 1.5 mg/l) in groundwater is a major problem in many parts of the world. Excessive fluoride (F) ingestion through drinking water is the principal causal factor of fluorosis (UNICEF, 1999). The fluoride is a great calcium-seeking element and it can disturb the structure of bones and teeth in the human body at higher concentrations causing dental or skeletal fluorosis (WHO, 2006). The Bureau of Indian Standards has recommended the permissible limit of F in drinking water as 1.0 mg/l (BIS, 2003), which is lower than the maximum tolerance limit (1.5mg/l) of F in drinking water stated by the World Health Organisation (WHO, 1984). More than 6 million people in 200 districts in India are seriously affected by “fluorosis” and another 62 million are unprotected to it (Mohapatra et al, 2004). In Rajasthan, 18 out of 32 districts are affected by fluorosis and 11 million people are at threat. This is due to large deposits of fluoride-containing minerals like fluorapatite, fluorspar and mica in Rajasthan (Hussain et al, 2011 and Shyam, 2011). The foremost source of ingestion of fluoride in our body is through drinking water. Fluoride in groundwater has been studied in the Nalgonda district (Ramamohan et al, 1993) Ranga Reddy district (Vijaya et al, 1993) and Guntur district (SubbaRao, 2003) of Andhra Pradesh. Considering this factor and keeping the importance because of public health, this study is designed to understand the present status of fluoride, it’s the implication on human health and mitigation strategies for fluoride problems in the groundwater of Sikar district, Rajasthan.

The Sikar district is located in the north-eastern part of Rajasthan between 27°21' and 28°12' North latitudes and 74°44' and 75°25' East longitudes at an average height of 432 m above the mean sea level. The Sikar district spreads over 7,732 Sq. km. and administratively, includes eight blocks, namely Fatehpur, Lachhmangarh, Dhod, Piprali, DantaRamgarh, Khandela, NeemKa Thana and Sri Madhopur (Figure 1).The district is divided into two main topographic regions. The western part is characterized by dunes and the eastern by Aravali hill ranges. There are no perennial rivers in the district. The main

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seasonal rivers are Kantli and Mendha. The climate of the district is characterized by a hot summer, scanty rainfall, chilly winter season and general dryness of the air except during monsoon season. The rainfall is very low, highly indefinite and variable. The total population of the district is 2.6 million (Census of India, 2011) with a density of 346 persons per Sq. km, which is quite high in comparison to the State density (201 persons/ Sq. km). The Sikar district is facing a rapid increase in population, development and industrialization while the groundwater resource availability is quite limited and scarce, that's resulting in groundwater quality deterioration. Thus, the Sikar district is selected for the study. Besides, deep familiarity with the area is another aspect for the selection of the district (CGWB. 2013).

Figure 1. Location Map of Sikar District, Rajasthan. Source: Self- Composed.

The major part of the district is covered with alluvial and Aeolian sand layers and the eastern part of the district is occupied by hills of the Aravali range. Delhi Super Group of meta-sediments exposed whose exposures are seen in Neemka Thana block in the eastern part of the district. The Delhi Super Group rocks are divided into Alwar and Ajabgarh Groups which can be seen in the eastern part of the district characterized by quartzite, slate, marble, schist and phyllite. Quaternary geological formation comprising of Alluvium (composed of sand, silt, clay and gravel) is the major and potential aquifer in the area. The most important mineral deposits in the Sikar are calcite, dolomite, fluorspar, soapstone, clay, limestone and building stones (CGWB, 2004). Many areas of Sikar city and its surroundings have shown the fluoride level more than the permissible limit. The fluoride level in the groundwater of Sikar may be due to some geological process such as the dissolution of fluoride-rich mineral (fluorspar) in the environment of alkaline pH, excess of bicarbonates, evaporation, semi aridity and high temperature.

The main objectives of the paper are: 1) To assess the fluoride contamination status and to understand its spatial variation. 2) To examine its implication on human health in Sikar district. 3)To suggest Mitigation Strategies for a sustainable future in the study region.

DATABASE AND METHODOLGY

The Study is based on secondary sources of data. The secondary data has been collected from various government departments like Department of Irrigation and Water Resource, Department of Agriculture, Central Groundwater Board (CGWB, Jaipur), Public Health and Engineering Department (PHED, Sikar), Directorate of Economics and Statistics, Jaipur and so on. Data results have been represented with the help of various cartographic techniques.

The Fluoride concentration map is presented in Figure 2. Fluoride concentration in groundwater ranges from 0.10 mg/l to 7.25 mg/l. A higher fluoride concentration (14.28 mg/l) has been observed at Dukia village. The Area in the central and eastern part of the district that occupies almost 63% of the district has a low concentration of fluoride (i.e., >1.5 mg/l) where the groundwater is suitable for domestic purposes. The areas with moderately high concentration (1.5-3.0 mg/l) occupy approximately 31% of the district area which are seen as NE-SW trending belts in the western and central parts of the district. High Fluoride concentration (>3.0 mg/l) occupies remaining almost 6% of the northern part of Fatehpur. The groundwater in this region is not suitable for domestic purposes. Fluoride concentration beyond permissible limit has been observed in parts of Fatehpur, Lachhmangarh, Khandela, Dhod and DantaRamgarh blocks (Table 1).

Table 1: Block wise area of Fluoride distribution in Sikar District

Fluoride Concentration Range (mg/l)	Block wise area coverage (sq. km)								Total Area (sq. km)
	Lachhmangarh		NeemKa Thana		Piprali		Sri Madhopur		
	Area	%	Area	%	Area	%	Area	%	
< 1.5	476.0	46.3	847.4	86.6	733.6	99.5	348.7	60	4645
1.5- 3.0	499.5	48.6	128.5	13.1	2.6	0.4	233.0	40	2288
> 3.0	52.4	5.1	3.2	0.3	0.6	0.1	-	-	440.6
Fluoride Concentration Range (mg/l)	Block wise area coverage (sq. km)								Total Area (sq. km)
	Danta Ramgarh		Dhod		Fatehpur		Khandela		
	Area	%	Area	%	Area	%	Area	%	
< 1.5	892.7	78.2	714.5	78.9	237.8	19.7	394.2	49.5	4645
1.5- 3.0	163.0	14.3	183.6	20.3	699.5	58.1	378.2	47.5	2288
> 3.0	85.2	7.5	7.2	0.8	267.8	22.2	24.2	3.0	440.6

Source : Hyderological Atlas, Sikar District, Rajasthan, CGWB, Jaipur, 2005-2009

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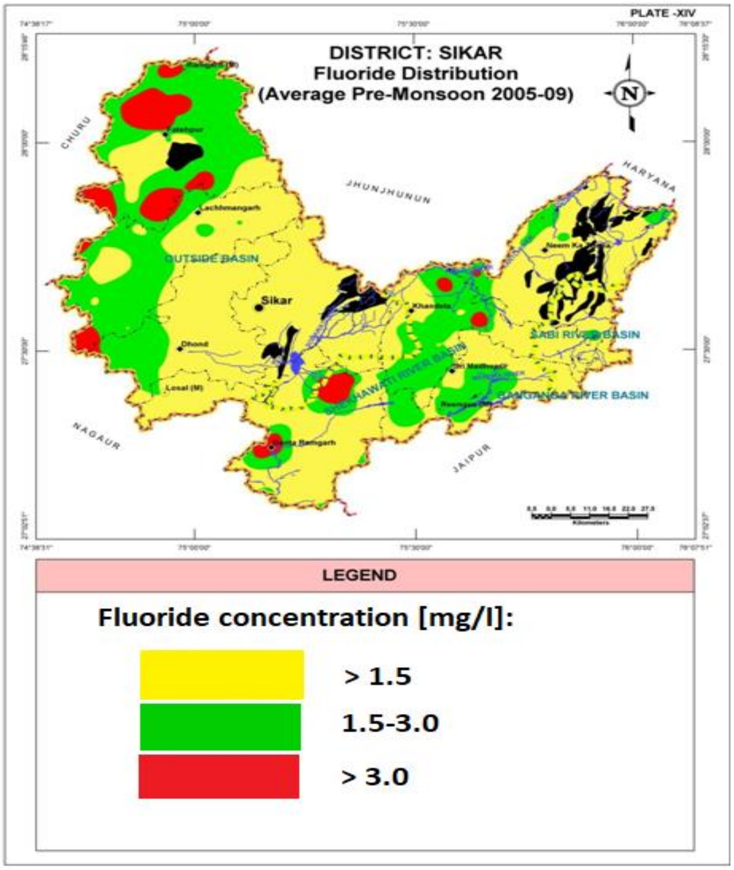

Figure 2 : Fluoride concentration map of Sikar District. Source: NATMO

Effects of fluoride on human health: Fluoride is essential for the normal maintenance of teeth and bones. Persistent exposure to a high concentration of fluoride is found to be damaging to teeth, bones and other organs. Fluoride contamination is a major health hazard in many parts of the world. World Health Organization has shown the correlation between fluoride and biological effect (WHO, 1996).

Table 2.Concentration of fluoride and its harmful effects on Human Health

Fluoride in drinking water (mg/l)	Concentration Effects
0.002 mg/l in air	Injury to vegetation
1 mg/l in water	Dental caries reduction
. 3.1 to 6.0 mg/l in water	Mottled enamel
8 mg/l in water	10% osteoporosis
20–80 mg/day or more	Crippling skeletal fluorosis, possibly cancer
50 mg/l in food or water	Thyroid change
100 mg/l in food or water	Growth retardation
More than 125 mg/l in food or water	Kidney change
2.5 – 5.0 gm in actual dose	Death

Source: WHO, 1996

Dental fluorosis or effect on dental enamel: Dental fluorosis is caused by the intake of excess levels of fluoride, particularly from birth to the age of eight. In dental fluorosis, excessive fluoride usually causes yellowing of teeth, white spots, and pitting or mottling of the enamel. Dental fluorosis affects both the inner and outer surface of the teeth.

Osteoporosis: Above 4 mg/l Fluoride intake in drinking water may cause an ailment of dense and brittle bones known as Osteoporosis.

Skeleton fluorosis: Prolong and excessive fluoride(> 8 mg/l in water) ingestion may also result in slow, progressive crippling scourge known as skeletal fluorosis. Skeletal fluorosis affects the bones/skeleton of the body. It causes pain and damage to bones and joints. The joints which are normally affected by skeletal fluorosis are the neck, hip, shoulder and knee. Fluoride mainly gets deposited in these joints and makes it difficult to walk or move.

Gastrointestinal effects: The primary gastrointestinal effects following both acute and chronic oral exposure to fluoride consist of nausea, vomiting, and gastric pain. The irritation of the gastric mucosa is attributed to fluoride (as sodium fluoride) forming hydrofluoric acid in the acidic environment of the stomach. Apart from bones and teeth excess ingestion of fluoride can damage or impart ill effects on other soft tissues and organs also, categorized as non-skeletal fluorosis. The symptoms include gastrointestinal complaints, loss of appetite, pain in the stomach, constipation followed by intermittent diarrhea.

Endocrine effects: Considerable attention has consequently been given in recent years to the behavior of fluoride in hormone chemistry and the possible and the possible clinical disturbances of endocrine function, particularly the thyroid gland.

Cardiovascular effects: The cardiovascular effects of fluoride have been accredited to hypo-calcemia and hyper-calemia caused by high fluoride levels. Fluoride can bind with serum calcium and causes hypocalcemia. Calcium is necessary for the functional integrity of the voluntary and autonomic nervous systems. Hypocalcemia can cause decreased myocardial contractility and possibly cardiovascular collapse.

MITIGATION AND THE PREVENTION OF HYDROFLUOROSIS

The traditional method of removing fluoride from drinking water is treating with lime and the accompanying precipitation of fluorite. Defluoridation of water can be done by adopting appropriate techniques at both the domestic and the community levels. Although several defluoridation techniques are available, the Nalgonda technique is one of the widely used defluoridation techniques because it is simple, effective, and low-cost. The process comprises the addition of prescribed quantities of alum, lime, and bleaching powder to raw water, followed by rapid mixing, flocculation, sedimentation, filtration, and disinfection. After adding alum and lime to the raw water, insoluble aluminum hydroxide flocs are formed, sediment to the bottom and co-precipitate fluoride and bleaching powder ensures disinfection during the process. The harvesting and conserving of rainwater is a better method for obtaining low fluoride water. The people of western Rajasthan have been practicing rainwater harvesting, by collecting rainwater from rooftops or pucca surfaces or collecting it in small surface ponds.

RECOMMENDATIONS

- Artificial recharge measures like small check dams, anicuts and earthen dams may be constructed at possible sites to store rainwater and surplus runoff from the area. This will increase the recharge of the groundwater bodies.
- Watershed development programs and control of soil erosion activities should be stimulated in the area.
- Surface runoff can be harnessed by artificial tanks at feasible sites in the eastern part of the district for supplementing irrigation potential to increase agricultural production.
- Modern agriculture management techniques have to be implemented for effective and optimum utilization of water resources.
- It is essential to specifically identify the freshwater aquifers through Cement sealing should also be done precisely to seal off the saline aquifer.
- Over-exploitation disturbs the hydro-chemical balance of fresh groundwater leading to contamination of saline water ingress. Therefore, the Clustering of tube wells should also be avoided.
- There is a need to educate people to make them aware of the importance of groundwater for better practices of water use in domestic, irrigation and industrial sectors.
- It is suggested that rainwater harvesting is one of the ways to dilute the fluoride concentrations in goundwater and helps to avoid excessive fluoride ingestion in the present study region.
- Various developmental activities over the years have adversely affected the groundwater regime in the district. There is a need for scientific planning in the development of groundwater under different hydrogeological situations and to develop effective management practices with the involvement of the community for better groundwater governance.
- Defluoridation of water can be done by adopting appropriate defluoridation techniques at both the domestic and the community levels. Although several defluoridation techniques are available, one of them, the Nalgonda defluoridation technique is simple, effective, and low-cost.

CONCLUSION

This study provides an overview of the fluoride contamination status of groundwater in Sikar district. The level of fluoride contamination in the groundwater of Sikar district is beyond the permissible limit as per BIS and WHO standards. The groundwater in this region is not suitable for domestic purposes. Weathering of fluoride bearing rocks and leaching of fluoride are the major reasons for the elevated concentration of fluoride in groundwater in the study area. Fluoride rich minerals are decomposed/ dissociated from the source - rock and F are dissolved in the groundwater. The influence of local lithology, aided by other factors like the semi-arid climate of the region is also responsible for a higher concentration of F in the groundwater of the region. The northern part of Fatehpur and NE-SW trending belts in the western and central parts of the district have high Fluoride concentration. Numerous dental and skeletal diseases have been reported in the district due to high fluoride concentration in groundwater. Suitable measures such as defluorinating the groundwater before use and recharging the groundwater by rainwater harvesting need to be practiced to improve the groundwater quality in the area. A good and balanced mix of appropriate technology with adequate community participation can only be an effective answer to combat fluoride.

REFERENCES

CGWB. 2004. Annual report and other related reports on groundwater quality. Ministry of water resources. New Delhi.

CGWB. 2013. Ground water scenario, Sikar District, Rajasthan. Ministry of water resources. New Delhi.

Hussain, I. Arif, M. Hussain, J. 2011. Fluoride contamination in drinking water in rural habitations of central Rajasthan, India. Environmental monitoring and assessment.

Mohapatra, D. Mishra, D. Mishra, S. P. Chaudhury, G. R. & Das, R. P. 2004. Use of oxide minerals to abate fluoride from water, Journal of Colloid and Interface Science, 275(2). 355–359.

Rao, Ramamohan. Suryaprakas, N. V. K. Rao, & Schuiling, R. D. 1993. Fluorine distribution in waters of Nalgonda District, Andhra Pradesh, India. Environmental Geology, 84–89.

Shyam, R. Kalwania, G. S. 2011. Ground water chemistry: A case study of eastern part of Sikar city (Rajasthan), India, International Journal of Applied Engineering Research, 2(2). 367–378.

Srinivasa, R. Bhakara, P. & Singha, A.P. 2015. Groundwater Quality Assessment in some selected area of Rajasthan, India Using Fuzzy Multi-Criteria Decision Making Tool, International Conference On Water Resources, Coastal And Ocean Engineering (ICWRCOE 2015,Aquatic Procedia, (4). 1023 – 1030.

Subba Rao, N. 2003. Groundwater quality: Focus on fluoride concentration in rural parts of Guntur district, Andhra Pradesh, India, Hydrological sciences, 48(5). 835–847.

UNICEF. 1999. State of art report on the extent of fluoride in drinking water and the resulting endemicity in India, UNICEF, New Delhi.

Vijaya Kumar, V. Sai, C. S. T. Rao, P. L. K. M., & Rao, C. S. 1991. Studies on the distribution of fluoride in drinking water sources in Medchal Block, Ranga Reddy District, Andhra Pradesh, India. Journal of Fluorine Chemistry. 55(3). 229–236.

WHO. 2006. Fluoride in drinking water, World Health Organization, IWA publishing, London.

WHO. 1984. Guidelines for drinking water quality, Health Criteria and Other Supporting Information. World Health Organization, Geneva. Vol. 2.

WHO. 1996. Guideline for drinking water quality, Health criteria and other supporting information, World Health Organization, 2(2). Geneva.

Received: 23th June 2021; Accepted: 10th March 2021; First distribution: 10th April 2022.