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Analysis and Visualization of the Fluoride Hazard Quotient in the Groundwater of Rural Areas in Northwestern Region of Ajmer District, Rajasthan, India

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Abstract: Groundwater contamination by fluoride is a major concern in many regions of India. Fluoride in excess is one of the most harmful pollutants to human health. Water contains about 80% of the total fluoride acquired in the human body (mg/kg/day). The health risks connected with fluoride-rich ground water must be evaluated. Ajmer district (25°38'-26°58' N: 73°54'-75°22' E) covers an area of 8481 km2. The district's principal geomorphic characteristics include alluvial plains, linear ridges, pediment, denudation hill, buried pediment, and structural valleys. During this study, 15 villages in the northwestern district of Ajmer were sampled. The fluoride exposure dose, which is an individual's chronic daily absorption of fluoride by eating, was determined for infants, children, and adults; a hazard quotient greater than one suggests the possibility of detrimental health effects. The Hazard Quotient for fluoride in the research region was mapped using Inverse Distance Weighting (IDW) interpolation. The HQ analysis showed that all readings above the permissible limit of one, with values ranging from 1.01 for Pushkar to 4.38 for nearby Hokhra. The average fluoride value for the whole research region was 2.73, with a standard deviation of 0.950. Fluorosis appears to be caused mostly by fluoride-rich waterways in the region. Decomposition, dissociation, and dissolution are the primary chemical events responsible for fluoride mobility and transit into groundwater. Low-cost fluoride control strategies include mixing, artificial recharge, effective irrigation systems, and well construction.
Keywords: Fluoride, Risk Analysis, Spatial Mapping, Ajmer, Hazard assessment.

I. INTRODUCTION

Fluoride in groundwater is one of the key contaminants that can harm human health. Because fluorine is plentiful in the earth's crust, it is found as dissolved fluoride in groundwater all around the world. Whereas 0.7-1.0 mg/l of fluoride in drinking water is required to prevent dental cavities and tooth decay, too much fluoride (1.5 mg/l) can cause dental and skeletal fluorosis. Although fluoride's primary target organ is bones, it has also been linked to impaired brain development in youngsters, lower IQ (Xu et al. 2020), hypothyroidism, hyperglycemia, infertility (Dey and Giri 2016), and osteosarcoma (Cohn 1992). There are several papers on fluoride exposure and risk analysis through food or drinking water, although the majority of the reports focus on the negative consequences associated with fluoride-rich drinking water. Fluorite (CaF2) and fluorapatite (Ca_5(PO4)3F) found in soil as natural minerals react with ground water, contaminating drinking water, particularly in rural and remote places (Haritash et al. 2018). Because the geographical distribution of fluoride-rich minerals is greater in Rajasthan soil, the majority of groundwater sources in India have comparatively higher fluoride concentrations (>1.0 mg/l) (Arif et al. 2013). According to reports, fluoride has polluted 50% of ground water supplies, on which more than 90% of rural drinking water delivery programmes rely. Given that ground water is India's primary supply of drinking water, a full knowledge of the geochemistry of fluoride in ground water looks increasingly important (Sharma et al., 2011).

According to studies, drinking water accounts for about 80% of total fluoride collected in the human body (mg/kg/day). As a result, assessing the health risks connected with fluoride-rich ground water is important.

As a response, the current study was carried out to evaluate the fluoride level in groundwater in villages in the northern portion of Ajmer District, Rajasthan state, India. Furthermore, the exposure assessment and risk were computed using the approach recommended by the USEPA (1993).

II. MATERIALS AND METHODS

Ajmer district (25°38'-26°58' N: 73°54'- 75°22' E) covers an area of 8481 km^2, The district's principal geomorphic characteristics include alluvial plains, linear ridges, pediment, denudation hill, buried pediment, and structural valleys. The Aravalli range, which dominates the western section of the region and operates as a significant groundwater boundary, is the most defining geomorphic feature. The Banas is the most major river, although the region is also drained by tributaries and a few minor ephemeral rivers such as the Khari. Although groundwater exists mostly under the water table in all strata, the Quaternary alluvium produces excellent aquifers in areas of the Ajmer district. Secondary porosity, such as cracks, fissures, joints, foliation, and so on, controls the occurrence and flow of groundwater in hard rock terrain. Water abounds in the worn layer of unyielding rocks. For the study purpose, Northern region of the Ajmer was selected (figure 1) and water samples from following villages were analyzed.

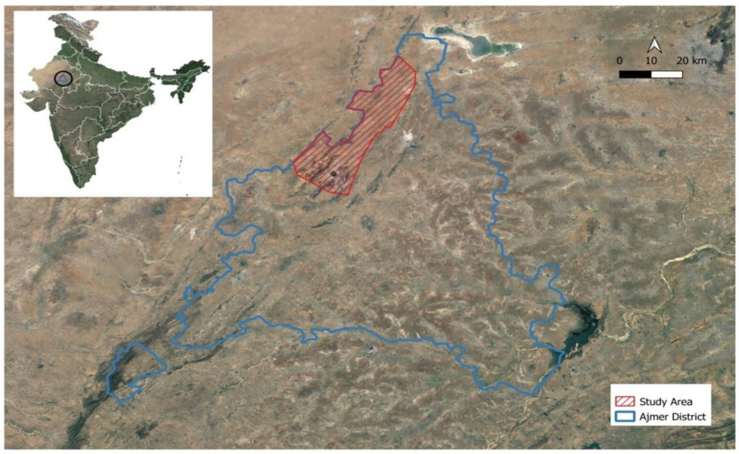

Figure 1: Study area

Water samples were collected and analyzed from these fifteen sampling site (Table 1). A total of sixty groundwater samples from these villages were collected, 4 from each site in pre-cleaned polythene bottles with necessary precautions (Brown et. al. 1974). The samples were collected, from January 2022 to October 2022 at manually operated hand pumps. The analysis fluoride content in water was done by SPADNS Spectrophotometric Method and the exposure assessment and risk analysis were performed using the methodology as given by USEPA (1993)

Table 1: List of sampling sites

S.no	Sampling site	Coordinates
1	Ajmer	26.49N 74.63E
2	Amarpura	26.71N 74.69E
3	Ararka	26.63N 74.72E
4	Babaychya	26.68N 74.73E
5	Chanchiyawas	26.56N 74.67E
6	Ghooghra ghati	26.50N 74.68E
7	Hokhra	26.54N 74.60E
8	Kanas	26.52N 74.58E
9	Kayad	26.53N 74.68E
10	Kharkedi	26.74N 74.71E
11	Lohagal	26.51N 74.65E
12	Narwar	26.59N 74.68E
13	Pushkar	26.49N 74.55E
14	Roopangarh	26.79N 74.84E
15	Salemabad	26.72N 74.79E

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The fluoride exposure dose is an individual's chronic daily consumption of fluoride from ingestion, and it was estimated, using following equation (USEPA 1992):

$$Exposure\ Dose\ (CDI) = \frac{C * WI}{BW}$$

Where C is the fluoride content (mg/L), WI is the daily water intake (Lt), and BW is bodyweight (kg). Water consumption and average body weights were calculated as 0.5, 1.5, and 3.0 L/day and 6, 20, and 70 kg, respectively, for infants, children, and adults (Viswanathan et al. 2009a; 2009b).

The non-carcinogenic risk of fluoride exposure was assessed using the hazardous quotient (HQ), which can be calculated using the following equation:

$$HQ = CDI/RfD$$

Where RfD denotes the reference dosage (mg/kg/day). Drinking water fluoride RfD levels are 0.05 mg/kg/day, was determined using the values provided by the Integrated risk information system (IRIS 2007). A HQ value greater than one indicates simply the possibility of danger. Because the USEPA process includes protective assumptions meant to offer a margin of safety while determining the reference dosage, a hazard quotient larger than one does not always indicate the likelihood of harmful consequences. As a result, this just implies that there is a possibility of negative health impacts. (IRIS 2007).

III. RESULTS AND DISCUSSION

Fluoride concentrations in the study region ranged from 0.79 to 3.26 mg/L on average (Table 2). Hokhra village has the highest concentration, followed by Babaychya, Roopagarh, Kharkedia, and Googhra. The concentration of fluoride within the allowed range (1.5 mg/L) was recorded at just four sample sites out of fifteen, which were Kayad, Pushkar, Chanchiyawas, and Kanas, and observations from the remaining eleven villages suggest that water de-fluoridation is required. The investigation revealed a wide range of fluoride concentration in groundwater from different villages. The findings also indicated that fluoride is not equally distributed in the groundwater of Ajmer's northern section. This fluctuation can be explained by the non-uniform distribution of fluoride-bearing minerals in host rocks and their interaction with water.

The chronic daily intake (CDI) and Hazard Quotient (HQ) of fluoride by oral consumption were determined for exposure assessment in terms of mg/day and mg/day/kg body weight (Table 2). The HQ of all sites using mean concentration were >1 more than one for all i.e. infant, child and adult, showing possibility of danger individually (Naz et al. 2016) and the mean value for HQ stands at 2.73 for northern region of Ajmer district. Fluoride use has been linked to a variety of health problems, ranging from nausea to neurological damage to death (Mullins et al. 1998). Fluoride's non-carcinogenic danger can manifest itself in three ways: dental, bone, and skeletal. The calculation of exposure dosage in this study only addresses fluoride consumption from drinking water and does not account for additional sources of fluoride therefore the actual exposure will be more than the exposure doses.

Table 2: Observation table.

S.No	Sampling Site	Average Fluoride	CDI	HQ			
				Infant	Child	Adult	Average
1	Ghooghra ghati	2.3525	0.196041667	3.920833	3.52875	2.016429	3.16
2	Lohagal	2.52	0.21	4.2	3.78	2.16	3.38
3	Ajmer	2.4	0.2	4	3.6	2.057143	3.22
4	Kayad	0.795	0.06625	1.325	1.1925	0.681429	1.07
5	Hokhra	3.2675	0.272291667	5.445833	4.90125	2.800714	4.38
6	Kanas	1.44	0.12	2.4	2.16	1.234286	1.93
7	Pushkar	0.755	0.062916667	1.258333	1.1325	0.647143	1.01
8	Chanchiyawas	1.44	0.12	2.4	2.16	1.234286	1.93
9	Narwar	1.72	0.143333333	2.866667	2.58	1.474286	2.31
10	Ararka	1.89	0.1575	3.15	2.835	1.62	2.54
11	Babaychya	2.6	0.216666667	4.333333	3.9	2.228571	3.49
12	Amarpura	1.895	0.157916667	3.158333	2.8425	1.624286	2.54
13	Kharkedi	2.5925	0.216041667	4.320833	3.88875	2.222143	3.48
14	Salemabad	2.3	0.191666667	3.833333	3.45	1.971429	3.08
15	Roopangarh	2.6	0.216666667	4.333333	3.9	2.228571	3.49
*CDI= Chronic Daily Intake, HQ= Hazard Quotient						Mean	2.73
						SD	0.950558

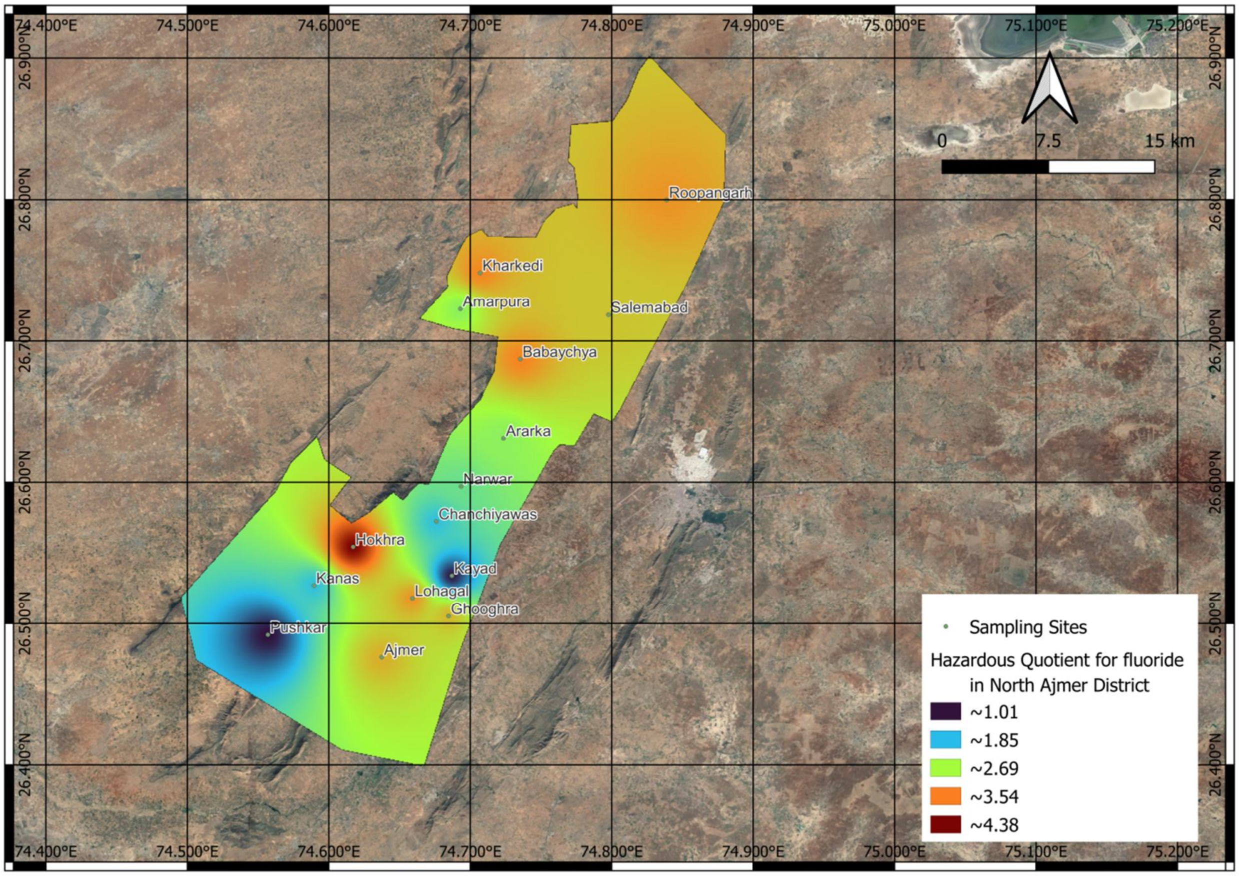

Figure 2: Mapping for Hazard Quotient for fluoride in study area.

The only way to avoid this is to limit your fluoride consumption to acceptable levels. Fluoride poisoning can be avoided or reduced by using other water sources, eliminating excess fluoride, and improving the nutritional state of the vulnerable population. Clinical studies show that adequate calcium consumption is definitely linked to a lower incidence of dental fluorosis (Teotia et al. 1987 and Karthikeyan 1999). Vitamin C may also help as a preventative measure. As a result, steps to enhance an affected population's nutritional quality, particularly in youngsters, appear to be a successful supplement for a fluorosis antidote.

IV. CONCLUSION

Most of the research region had Fluoride concentrations above the maximum allowable level (1.5 mg/l). The presence of fluoride-bearing minerals in host rocks, as well as their interaction with water, is thought to be the primary source of fluoride enrichment in groundwater. The key chemical reactions responsible for fluoride mobility and transit into groundwater are decomposition, dissociation, and dissolution. Chemical weathering in arid to semiarid environments with relatively high alkalinity and a lengthy residence period of interaction appears to have favoured high fluoride concentrations in groundwater. Regular use of fluoride-rich waters appears to be the primary reason of the region's high fluorosis incidence. Dilution by blending, artificial recharge, efficient irrigation methods, and well building are some popular low-cost fluoride management measures that may be implemented to improve community health.

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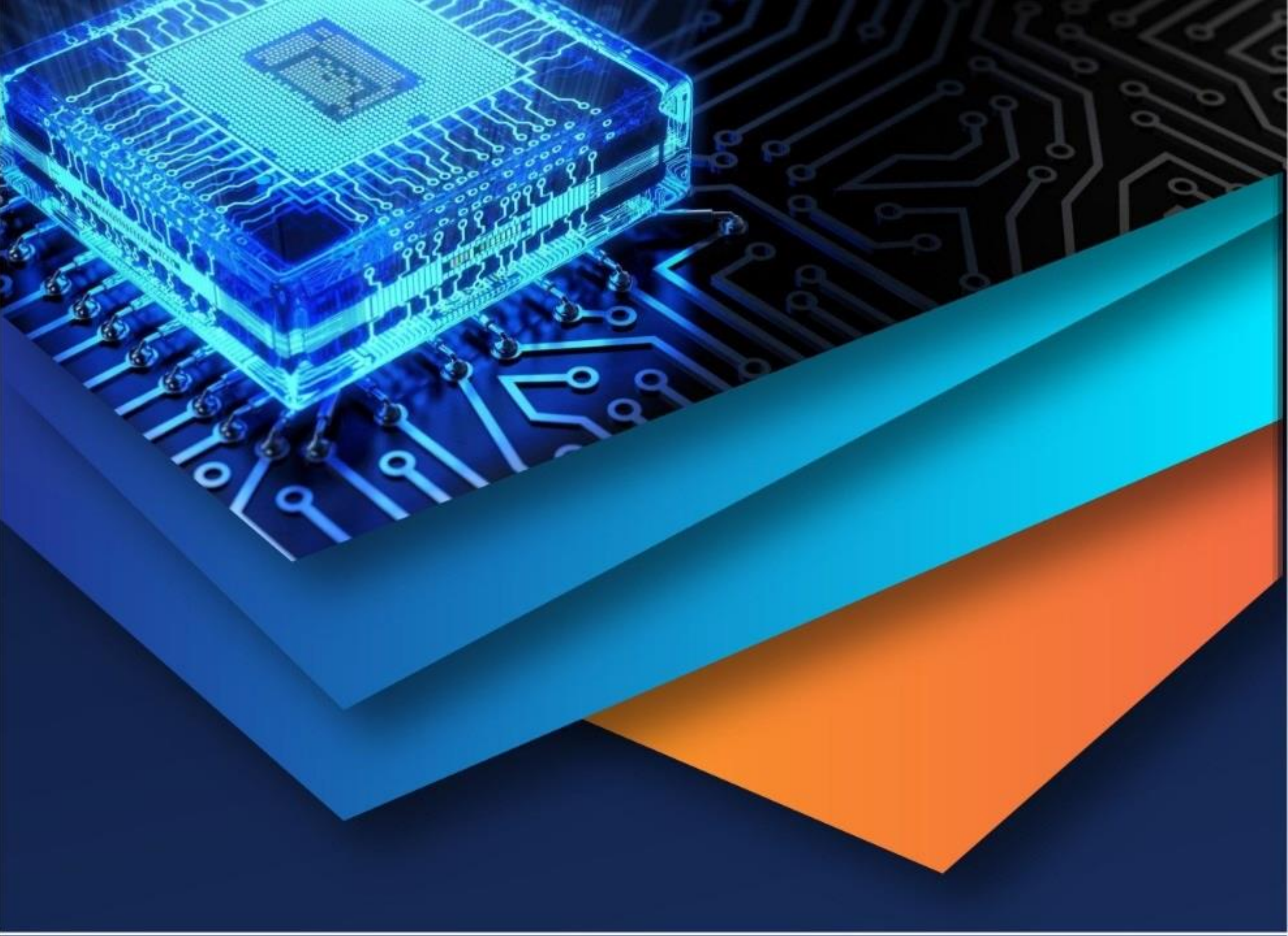

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