Assessment of Groundwater Fluoride Contamination's Negative Effects on Human Health in the Balod District of Chhattisgarh

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Abstract: The granitic and gneissic topography of the Archaean and Proterozoic periods in the Indian states of Chhattisgarh, Rajasthan, Andhra Pradesh, and Madhya Pradesh has numerous known occurrences of fluorosis, both oral and skeletal. The presence of harmful fluoride is thought to have its roots in geological processes. Comprehensive research is needed to understand fluoride behaviour in drinking water, especially in relation to hydrogeological settings, climate, and other aspects. Groundwater hydrogeology in the Balod district of Chhattisgarh, is the focus of the current investigation. The purpose of this research is to learn more about groundwater pollution from fluoride and to deduce the chemical factors that govern fluoride spread. Crystalline basement and Proterozoic sedimentary rocks (limestone, shale, and sandstone) provide the underlayment of the research area. In June 2023, 55 water samples were collected from wells that were dug or bored in the study region. According to the results, the water samples showed a wide range of physicochemical compositions. Alkaline pH levels ranging from 6.02 to 8.66, with an average of 7.34, were typically detected in groundwater. Fluoride concentrations ranged from 0.12 mg/l to 3.58 mg/l, according to the results of the chemical study. As groundwater interacted with fluoride-bearing minerals in the host rock, chemical reactions, dissociation, and dissolution increased groundwater fluoride concentration. The high fluoride content in groundwater is caused by chemical weathering and alkalinity. Dental and skeletal fluorosis were severe problems for the villagers since they had no choice but to drink the groundwater, which was highly fluoridated.

Keywords: Fluoride, Groundwater, Granitic terrain, Fluorosis, Balod

INTRODUCTION

Groundwater is primarily contaminated from geological sources, which is the main cause of the high concentrations of parameters such as fluoride, arsenic, iron, manganese, radon, and chromium (Shaji et al., 2024; Beg et al., 2011). The term "geogenic pollution of groundwater" describes the unnaturally high concentrations of harmful substances in groundwater. A problem with providing safe water in places affected by geogenic contamination of arsenic and fluoride is that it affects many portions of the nation (Marghade et al., 2023). pH, temperature, anion exchange capability of aquifer materials, solubility of fluorine-bearing minerals,water contact duration and water-drained geological formationsall influence fluoride concentration in drinking water (Sunkari et al., 2022). The quantity of fluoride (F^-) in water varies depending on geologic formations, aquifer materials' anion exchange capacity, fluoride-bearing minerals, pH, alkalinity, temperature, and residence period. Apatite, fluorite, amphiboles, mica,villiamite andclay mineralsare major minerals that influence fluoride hydrogeochemistry. Fluoride's colorless, tasteless, and odorless characteristics makes it impossible to assess its concentration by physical examination (Apparao et al., 2986).

Fluoride was found to be mobile and transported into groundwater through a series of chemical reactions including decomposition, dissociation, and dissolution. So, as several other researchers have noted, fluoride dissolves better in environments with an alkaline pH.The health benefits and risks of fluoride ions in drinking water are well-documented. Even in trace amounts, it is necessary for bone mineralization and tooth enamel production to proceed normally (Kanduti et al., 2016). Nevertheless, skeletal fluorosis and dental fluorosis can result from fluoride consumption at greater doses (>1.5 mg/l) and extremely high concentrations (>3.0 mg/l), respectively (Das et al., 2020). There is a limit of 1.0 mg/l for fluoride in drinking water set by the WHO, and another limit of 1.5 mg/l by the BIS (BIS, 1991). Nearly 6 million youngsters are among the 62 million individuals in India who are affected by fluorosis (WHO, 2006).

According to a research conducted by CGWB and Chhattisgarh State Public Health Engineering, fluoride levels in drinking water in 17 of Chhattisgarh's 27 districts exceed the permissible limit (Jhariya et al., 2017). Fluoride contamination affects several districts in Chhattisgarh, including Dhamtari, Gariyaband, Durg, Mahasamund, Balod, Kabirdham, Bemetara, SurajpurBastar, Bijapur, Kondagaon, Kanker, Korba, Surguja, Raigarh, Balrampur, and Koriya (Behead et al., 2012; Rubina et al., 2013). Because the issue of fluoride contamination in Balod District has received minimal attention thus far. Thus, this research seeks to identify fluoride levels in groundwater, its link to lithology, and its health effects.

Study area

Balod district, formed on January 1, 2012, is a town on the Tandula River's bank and serves as the district headquarters. The Tandula Dam, erected in 1912, is located adjacent to the district. The Tandula Dam, Kharkhara, and Gondli are the primary irrigation sources. Balod has an average elevation of 324 meters and a tropical wet-dry savanna climate. With an average rainfall of 1089.8mm, 93% of the rain falls between June and September. The study area map depicts both sample collecting locations and the study area. Figure 1 shows study area map.

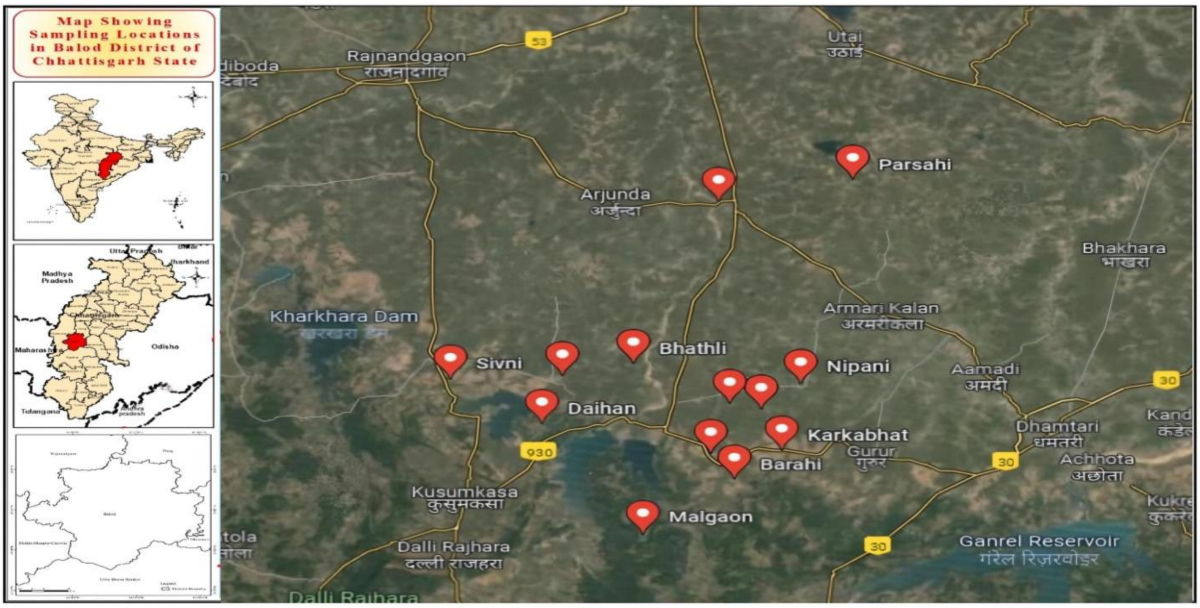

Figure 1 Google map of sample collection site

Geology and Hydrogeology

Archaean, Neoproterozoic, Quaternary, and Cenozoic rocks form the bulk of the area's underlayment (Chatterjee et al., 1998). The Eastern Ghat mobile belt and the Bengpal group, which date back to the Archaean period, are the oldest rocks found in the region. The rocks mostly consist of maghemite, amphibole, pyroxene, mica, white, garnetiferous, micaceous, magnetite, and quartzites from the Dharwarian epoch (Deshmukh et al., 1995). The area is covered in dykes formed by amphibolites and pyroxenites, and the rocks that are most common are gneisses (Handa et al., 1975).

Granitic gneiss and phyllites were the study area's primary litho-units; red, sandy soils covered them, and dendritic to sub-dendritic drainage occurred throughout. Pegmatite, dykes, and quartz veins are secondary intrusives that are present in the study area, but they are not very common. Under phreatic circumstances, groundwater can be found in weathered and cracked rock zones. The water table is located between 5.6 and 12.1 meters below ground level. The excavated wells can be anywhere from 2 to 7 meters in diameter and 8 to 13 meters in depth. For potable water, the hand pump has a maximum depth of 40 meters below earth.

MATERIALS AND METHODS

Samples of groundwater were taken in June 2023 using manual pumps. Using the conventional techniques, samples were evaluated for major ion chemistry at the laboratory . EC and pH meters measured electrical conductivity and pH. Use of the ionic calculation approach allowed for the estimation of total dissolved solids. Titration with HCL in 1000 cc of Burette digital Scott duran was used to measure total alkalinity (TA), CO3, and HCO3. Fluoride contamination in groundwater was investigated using titration with standard EDTA, and the results showed a total hardness (TH) of 91. An ESICO famous photometer (Model 1382) was used to measure Na and K. The usual method for estimating Cl was the AgNO3 titration. We used a UV-visible spectrophotometer (UVVIS-Model Cary 100 Bio) to measure fluoride, SO4, and calcium, and an atomic absorption spectrophotometer (AAS) to determine magnesium and iron. Ultraviolet spectrophotometer, absorbance spectrophotometer, and famous photometer chemicals are of A.R. grade. Heavy rains characterise the monsoons from June to September. This rainfall has the potential to help remove fluoride from soil into groundwater aquifers. The samples were taken in 500 ml plastic bottles that had been cleaned and sterilised beforehand. When collecting samples, every measure was taken to ensure their safety.

RESULT AND DISCUSSION

Hydrochemistry

In groundwater hydrology, water analyses are used to gather data about the water's quality (Nawlakhe et al., 1995). When deciding whether or not to use groundwater for agricultural, industrial, or drinking reasons, it is helpful to do a quality analysis. The physicochemical parameters of water quality, including pH, EC, TDS, and the concentrations of main anions and cations, as well as their minimum and maximum values, are displayed in (Table 1).

The data showed that the water samples varied greatly in terms of the physicochemical composition that they displayed. Alkaline groundwater is frequent in the research location (Mehta et al., 2010). The average pH is 7.34, ranging from 6.14 to 8.72. Most groundwater samples in the area are above 7.5, indicating alkaline water. While pH itself poses no threat to human health, it does have strong relationships to other water-based chemicals.

Several researchers have noted that fluoride is better soluble at alkaline pH, and this is supported by the fact that fluoride is adsorbed on clay surfaces in acidic water and desorbed from solid phases in alkaline water (Kullenberget al.,1973; Kundu et al., 2001). EC in this research varied between 2.12 and 1802µs/cm. Table 1 shows that the entire research region lies between 1.41 and 1204.12 mg/l, according to the distribution of TDS values. Hardness ranged from 188 to 1739 mg/l. Table 1 shows that chloride levels vary from 29 to 355 mg/l, averaging 91.2 mg/l. An average of 37.54 mg/l of nitrate ions was present, with a range of 24 to 64 mg/l.

Table 1 Study region drinking water standards compared to WHO (2006) and ISI (2010) for minimum, maximum, and mean ion concentration

Parameters	Minimum	Maximum	Average	WHO (2006)	Maximum limit	Highest Permissible limit NR
EC (µs/cm)	2.12	1802	994.22	750		
pH	6.02	8.66	7.28	7.0-8.5	6.5-8.5	NR
Alkalinity (mg/l)	188	578	400		200	600
TDS (mg/l)	1.41	1204.12	668.3	500	500	2000
$Ca2^+$ (mg/l)	33.11	334.23	81.24	75	75	200
Hardness (mg/l)	188	1739	414.12	500	300	600
Na^+ (mg/l)	0	212	68.11	200		
$Mg2^+$(mg/l)	0	243.3	50.93	30	30	100
K^+ (mg/l)	0.32	47.1	3.03			
CO_3^{2-}(mg/l)	12.4	57.4	34.21			
HCO_3^- (mg/l)	63.34	404.21	232.24	200	200	600
SO_4^{2-}(mg/l)	0	833.2	46.23	200	200	400
Cl^- (mg/l)	29	355	91.2	250	250	1000
NO_3^- (mg/l)	24	64	37.45	50	45	NR
PO_4^{3-}(mg/l)	0	1	0.06			
Fe_2^+ (mg/l)	0	4.45	0.67		0.2	NR
F^- (mg/l)	0.1	3.45	1.65	0.6-1.5	1.0	1.5

Hydrochemical facies

The variation of hydrochemical facies in Balod district is shown in Table 2. The magnesium, calcium and biocarbonate ions were having higher number of samples i.e. 35. The percentage of sample fall was 63.63% for hydrochemical facies. This findings of the study was in agreement with the results of Vikas et al., 2009.

Table 2. Variation of hydrochemical facies in Balod -District

S.N.	Hydrochemical facies	Number of samples	Percentageof sample fall (%)
1	Mg, Ca, SO4, Cl	12	21.81%
2	K, Na, SO4, Cl	3	5.45%
3	K, Na, HCO3	5	9.09%
4	Mg, Ca, HCO3	35	63.63 %

Fluoride

Fluoride concentrations varied between 0.12 and 3.58 mg/l in the period 2023. Fluorite, topaz, and fluorapatite are minerals found in gneisses, charnockites, and pegmatite-rich fractured hard rock terrains, which are underlain by areas of groundwater that is rich in fluoride (Rao et al., 2003; Rao et al., 2009). The same minerals were found in A.P. by Ramesham and Rajagopalan (1985). The residence duration of the chemical reaction, as well as their decomposition, dissociation, and dissolution activities, determine the concentration of F^- in groundwater. Because these minerals leached their fluoride ions into the groundwater, the quantity of fluoride in the water is quite high (Handa 1975). Common locations for fluorspar, also known as fluorite [CaF_2], include shear fractures, joints, and the interface between the host rock and the vein quartz. According to Jacks et al. (1980), calcium and magnesium carbonates are produced during chemical weathering, also known as hydrolysis, of minerals. These carbonates are excellent in soaking up fluoride ions.

Water fluoride levels depend on the leachable state of fluoride ions, which is affected by draining solution pH and soil dissolved carbon dioxide. To make fluoride in groundwater more effective, it needs the right amount of time to dwell there and ideal physicochemical conditions. Amphibolites, dolerite dyke, quartz veins, and pegmatites are sporadically visible within the Archean-aged crystalline charnockite and granitic gneiss that makes up the research area. Acid charnockite contains coarse-grained minerals that could contain fluoride, such as quartz, k-feldspar, hypersthene, and biotite.

Effect of fluoride on adults and children

Depending on the concentration, fluoride in water can be either beneficial or harmful to health (Wodeyar et al., 1996). The BIS and ICMR recommended doses up to 1.0 mg/l, whereas levels exceeding 1.5 mg/l are dangerous. These recommendations depend on local climate and total fluoride consumption from other sources because environmental temperature impacts body fluid fluoride absorption.Fluorosis occurs when fluorides deposit in hard and soft tissues. Fluorosis is frequent in this region due to high water fluoride levels, according to several studies. Drinking water with fluoride levels above 1.5 mg/l can cause tooth and bone fluorosis. Fluoride causes fluorosis, a severe disease that affects every organ, tissue, and cell (Figure 1). Fluorosis symptoms resemble gout, osteoporosis, and others. Fluoride damages the brain's pineal gland, which releases melatonin. The reproductive and IQ systems are affected (Susheela, 2001). Many fluorosis symptoms resemble osteoporosis and arthritis. Drinking unsafe fluoride-containing water may cause premature ageing, skeletal fluorosis, broken teeth, joint pain, and crippled limbs in many research region residents. It is frequent in areas with acidic groundwater and little calcium, which increases fluoride concentration. In addition to the on-site clinical assessment, a survey was also administered at the school level. Children were more likely to experience oral fluorosis, whereas adults were more likely to experience skeletal fluorosis, according to the survey study (Table 3). An deformity known as kyphosis is more common in older women and younger girls. Dental fluorosis affects adults (figure 3) at a higher rate than children (figure 4) . The majority of cases of fluorosis in the study region were dental in nature

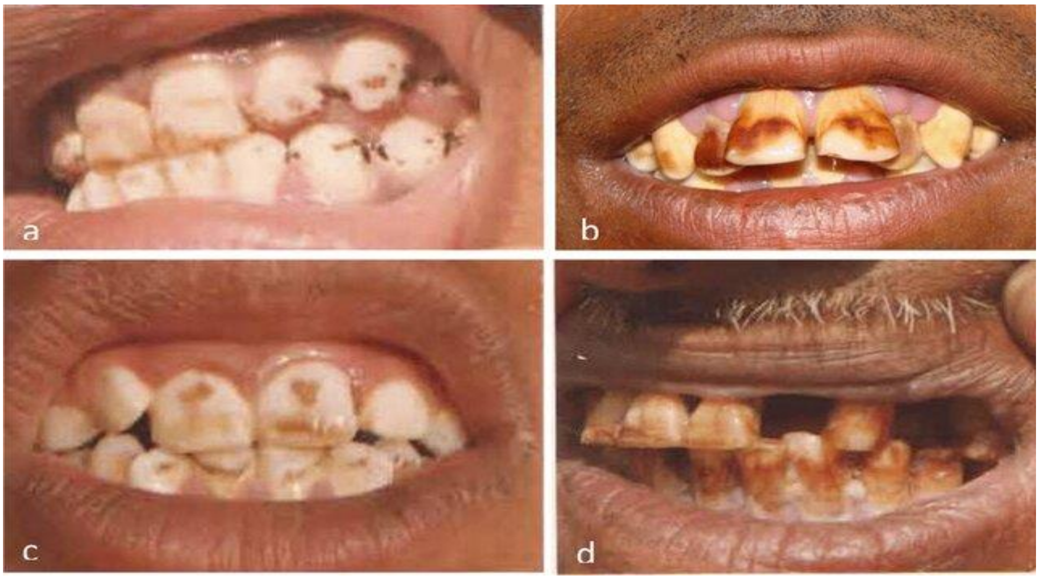

Figure 2 Dental flurosis in adult and child

Figure 2 Varieties of dental fluorosis in young, middle-aged, and elderly individuals. Horizontal streaks on teeth (b, d) and bilateral stratified spots or patches of light to deep brownish yellow and tiny specks or granules (a, c) are the hallmarks of dental fluorosis. Subject (d) is an elderly person with advanced dental fluorosis, which manifests as tooth wear, diastema, and recession of the gums.

Table 3Prevalence of dental fluorosis in Balod district of Chhattisgarh due to ground water contamination

S.N.	Villages	Fluoride content in water (ppm)	Subject studied	Subjects/ Cases	Dental fluorosis (%)
1	Angari	1.3-3.9	Adult	9	42
2	Baghmara	1.3-3.9	Adult	17	53
3	Barahi	1.3-3.9	Children	16	20
4	Bhothali	1.3-3.9	Adult	3	42
5	Daihan	0.8-5.3	Children	7	11
6	Ghumka	0.8-5.3	Adult	4	68
7	Kande	0.8-5.3	Adult	4	48
8	Karka Bhat	1.2-6.5	Children	0	15
9	Khapri	1.2-6.5	Children	6	30
10	Limora	1.2-6.5	Adult	9	79
11	Malgaon	1.2-6.5	Children	6	20
12	Nipani	1.3-6.8	Children	3	25
13	Parsahi	1.3-6.8	Adult	10	58
14	Siwani	1.3-6.8	Children	4	25

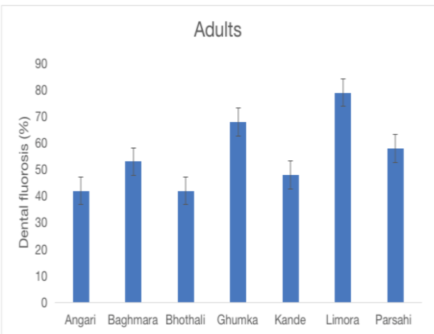

Figure 3 Dental fluorosis in adults

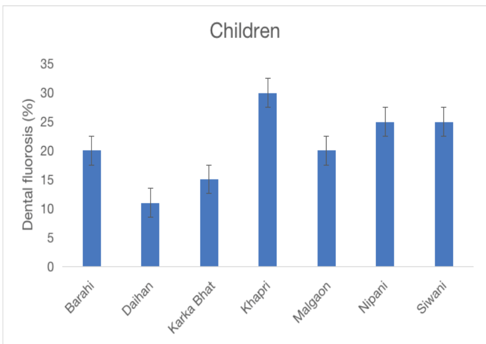

Figure 4 Dental fluorosis in children

CONCLUSION

Children and adults had more dental fluorosis. Human skeletal fluorosis was more common in people over 45 than in children.Current research found fluoride values from 0.1 to 5.94 mg/l. People near Balod have high fluoride levels. According to the study, fluoride-containing minerals in host rocks and their interactions with water are the main sources of groundwater fluoride enrichment. According to the results of the geographical investigation, the groundwater in the areas surrounding the Balod area is heavily polluted with fluoride. Fluorosis of the teeth, bones, and muscles have been reported in villages with high fluoride water consumption. Tube wells are essential for nearly all residents.

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