Geological aspects of fluoride contamination of groundwater in parts of western Odisha

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Abstract

The present work examines fluoride contamination of groundwater in different parts of Bargarh and Bolangir districts. The blocks worst affected by this problem include Barpali, Bijepur and Gaisilet blocks in the southern part of Bargarh district, and Agalpur, Belpada and Deogaon blocks in the northern part of Bolangir district. These blocks constitute a broadly NE-SW trending belt of fluoride contamination. Groundwater in the area occurs in both shallow and deep aquifers. Shallow aquifers are constituted by weathered formations where groundwater occurs under water table condition. Deep aquifers are constituted by fractured zones of the underlying bedrocks where groundwater occurs under semi-confined to confined condition. In deep aquifers, the fluoride concentration is up to 6.9 mg/L. Since the inhabitants of the region depend on the fluoride-contaminated groundwater for domestic needs, fluorosis is rampant in several parts of these districts. The study explores geogenic causes of fluoride contamination in the area.

IndexTerms: **Fluoride contamination, shallow and deep aquifers, Bargarh and Bolangir districts.**

1. INTRODUCTION

Enrichment of fluoride in groundwater is generally due to prolonged rock–water interaction, during which fluoride is released from the crystal structure of F-bearing minerals (Tripathy et al., 2005; Agrawal et al., 1997; Raju et al., 2009; Su et al., 2013;). The release is a function several factors including the mineralogy of rock, hydrogeological condition, groundwater chemistry, interaction period of groundwater with aquifer material, and the dissolution kinetics of F-bearing minerals (Nordstrom and Jenne, 1977; Deshmukh et al., 1995 and Rao, 2009). Prolonged chemical weathering of rocks over millions of years (Handa, 1975; Rao, 1997; Genxu and Guodong, 2001; Saxena and Ahmed, 2001; Edmunds and Smedley, 2005; Jacks et al., 2005; Chae et al., 2006; Sreedevi et al., 2006; Guo et al., 2007; Banerjee, 2015) have resulted in elevated contents of fluoride in groundwater in several parts of Odisha. Incidence of high fluoride (>1.5 mg/L) in groundwater is known from several districts including Bargarh, Bolangir, Nuapada, Kalahandi, Koraput, Anugul and Nayagarh. The present study focuses on geogenic causes of fluoride contamination of groundwater in parts of Bargarh and Bolangir districts where fluorosis is rampant due to excessive intake of fluoride through drinking water over a long period of time.

2. GEOMORPHOLOGY AND GEOLOGICAL SETTING

The topography of the Bargarh and Bolangir districts is marked by both undulating plains (pediments) with residual hills, and areas with high hills. The highest peak is Gandhamardan (983 m above mean sea level). The rivers Tel and Ong and their tributaries constitute the main drainage system in the area

and flow from west to east. The rainfalls are in the range of 1000–1500 mm in different parts of the two districts (CGWB, 2013; ORA, 2014).

Geologically, the area is a hard rock terrane, and falls near the contact between the Proterozoic Eastern Ghats Mobile Belt (EGMB) and the Bastar craton (Mahalik, 1996; Ramakrishnan and Vaidyanadhan, 2008; GSI, 2010; Sahu et al., 2013) (Fig. 1). The southern part of the area covering Bolangir district falls mostly within the EGMB, whereas the northern part of the area covering Bargarh district falls within the Bastar craton. The EGMB sector comprises a variety of rocks including leptynite, khondalite, megacrystic granitoid, charnockite, and anorthosite of the Bolangir Anorthosite Complex. On the other hand, the cratonic part is occupied by granitic gneiss of Archaean age. A stretch of east-west trending sedimentary rocks of the Lower Gondwana sequence is exposed close to the contact between the EGMB and the Bastar craton. Since the rock types of the area are varied, the geogenic sources of fluoride in the region is diverse, complicated and remain unconstrained.

Groundwater in the area occurs in both shallow and deep aquifers. Shallow aquifers are constituted by weathered formations where groundwater occurs under water table condition (Gore et al., 1998; Chandra et al, 2015). Deep aquifers are constituted by fractured zones of the underlying bedrocks where groundwater occurs under semi-confined to confined condition (Wright, 1992; Chandra et al., 2012; Gupta et al., 2015). The depth to water level in the year 2011 was 1.33-8.85 metres below ground level (mbgl) during pre-monsoon season and 0.78 mbgl to 6.85 mbgl during post-monsoon season in shallow aquifers (CGWB, 2013).

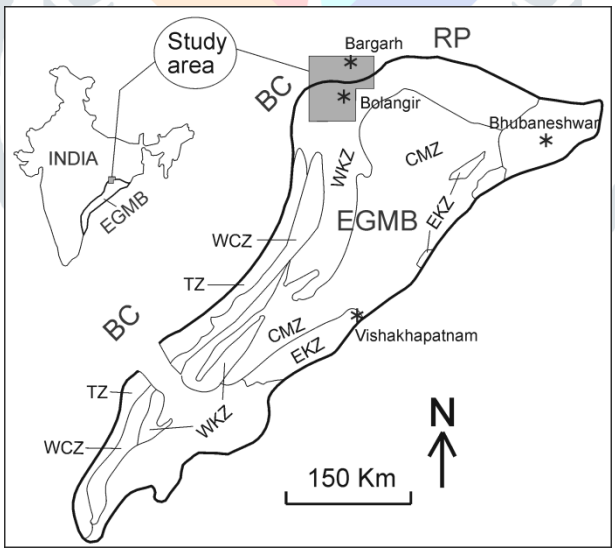

Fig. 1. Location of study area in reference to the Eastern Ghats Mobile Belt (EGMB). Inset shows the location of EGMB in India. Subdivision of EGMB into zones is after Ramakrishnan et al. (1998). BC - Bastar craton; CMZ- Central Migmatite-charnockite Zone; EKZ- Eastern Khondalite Zone; RP- Rengali Province; TZ- Transition Zone; WCZ- Western Charnockite Zone; WKZ-Western Khondalite Zone.

3. FLUORIDE CONTAMINATION OF GROUNDWATER

The World Health Organisation has prescribed the lower and upper limits of fluoride content in drinking water at 0.6 mg/L and 1.5 mg/L, respectively to be suitable for human consumption (WHO, 1993). Groundwater is said to be fluoride-contaminated if the fluoride content is above >1.5 mg/L. Fluoride

contaminated groundwater is known to occur in a broadly NE–SW trending belt covering Barpali, Bijepur and Gaisilet blocks in the southern part of Bargarh district, and Agalpur, Belpada and Deogaon blocks in the northern part of Bolangir district (Srivastava and Tiwari, 2006). In deep aquifers, the fluoride concentration has been found to be up to 6.9 mg/L which is much above the prescribed limit for drinking water (Table 1).

Table 1. Fluoride concentration at representative sites in Bargarh and Bolnagir districts.

Sl. No.	Block	Gram Panchayat	Village	Location	Fluoride (in mg/L)
(A) Bargarh district					
1	Barpali	Barguda	Haldipali	Majhibasti	4.4
2	Barpali	Satalma	Sikirdi	Harijanpada	3.2
3	Bheden	Mahulpali	Bhankud	Dashpada	3.8
4	Bijepur	Saipali	Putkigrinjel	Pr. school	3.6
5	Gaisilet	Buromunda	Buromunda	Maharpada	5.5
6	Gaisilet	Jagalpat	Badsahajbahal	Nuapada	6.9
(A) Bolangir district					
7	Agalpur	Jharnipali	Kudapali	Pr. School	3.5
8	Agalpur	Jharnipali	Patharmunda	Near pond	3.3
9	Belpada	Belpada	Padampur	Talpada	5.2
10	Deogaon	Gaibahal	Raipali	Basti	5.4
11	Deogaon	Badabandha	Budhabahal	Ranapada	3.4
12	Gudvela	Chinched	Chinched	Harijanpada	4.6

4. DISCUSSION AND CONCLUSIONS

Enrichment of fluoride in groundwater is attributed to prolonged rock-water interaction. Hydrous silicate minerals such as biotite, muscovite, hornblende and tourmaline contain significant amount of fluoride in their crystal structure. This is because, the ionic radius of fluoride (0.136 nm) is nearly the same as that of hydroxide ion (OH^-) and as a result, the two ions commonly substitute for one another in the crystal structure of the minerals. Other F-bearing minerals include fluorapatite [$Ca_3 (PO_4)_2(F,Cl)_2$] and fluorite (CaF_2). But the solubility of fluorite in fresh water is low and its dissolution rate is remarkably slow under normal temperature and pressure conditions (Nordstrom and Jenne 1977). Therefore, high F^- concentration in groundwater is more likely to result from the dissolution of silicate minerals and fluorapatite in the rocks.

For mitigation of fluoride contamination in shallow groundwater, a suitable managed aquifer recharge (MAR) method needs to be devised to dilute the fluoride concentration of groundwater in the region. However, before choosing recharge areas under MAR, a systematic, long-term monitoring of fluctuation in groundwater level and fluoride concentration needs to be undertaken. In this regard, it is crucial to understand the geology, weathering profile, and geochemical processes controlling groundwater chemistry in the area.

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