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Geochemical controls on fluoride concentrations in groundwater from alluvial aquifers of the Birbhum district, West Bengal, India

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ABSTRACT

Groundwaters with high fluoride (F^-) concentration up to 13.61 mg/L occur in some parts of the Quaternary alluvial aquifer of Birbhum district, West Bengal, India. The high F^- groundwater zones are mainly located in the discharge areas of Dwarka river basin, especially in places where groundwater occurs at a depth of 24–30 m within alluvial sediments, consisting of micaceous sand, silt and clay. Soil depth samples were collected from the 3 bore holes drilled up to about 30 m depth for geochemical analysis. Total F^- in the sedimentary material from the drilled holes measured about 400 to 450 mg/kg at deeper depth in CS1 and CS3 but no abnormal values found in CS2. XRD, XRF and total F^- analyses of sediments from aquifer zone reveal that, the presence of intercalated zeolitic clay within the aquifer sand is the major source of F^- in groundwater. Furthermore, geochemical investigations and laboratory analysis emphasize that sorption and de-sorption of intercalated zeolitic clay at different pH levels along with ion-exchange are the major mobilising factors for F^- in pre- and post-monsoon seasons. Most of the groundwater having fast recharge component either from flowing canals or rainfall, contains relatively depleted $\delta^{18}O$ content (−5 to −4‰). However, $\delta^{18}O$ content has no correlation either with Cl^- or F^- that shows more than one contaminant sources.

1. Introduction

Fluoride (F^-) although helpful in dental health in low dosage (<1.5 mg/L), it causes endemic dental and skeletal fluorosis when it exceeds the limit (Grandjean et al., 1992). Fluoride occurs in natural waters due to its high electronegativity and solubility (Liu and Liptak, 2000). Common natural sources of F^- in groundwater are the dissolution of fluorspar, fluorapatite, amphiboles (e.g., hornblende, tremolite) and some micas weathered from igneous and sedimentary rocks, especially shales (Datta et al., 1996). Unstable minerals, such as sepiolite and palygorskite may have a dominant control on F^- distribution in groundwater as well (Jacks et al., 2005).

Groundwaters in some locations all over the world were reported to have elevated F^- concentrations (Ayoob and Gupta, 2006; Brunt et al., 2004; Chae et al., 2007; Datta et al., 1996; Edmunds and Smedley, 2005; Gaciri and Davies, 1993; Guo et al., 2007; Handa, 1975; Jacks et al., 2005; Kim and Jeong, 2005; Reddy et al., 2010). In India, about 62 million people in 14 states and 150,000 villages are at risk due to fluorosis caused by high F^- drinking water (Andezhath et al., 1999; Pillai and Stanley, 2002). The problems are most pronounced in the states of Andhra Pradesh, Bihar, West Bengal, Gujarat, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh (Gupta et al., 1999; Pillai and Stanley, 2002).

Fluoride dynamics in igneous terrain is well-known (Edmunds and Smedley, 2005; Reddy et al., 2010; Shaji et al., 2007) in comparison to alluvium aquifers (Guo et al., 2010; Kim et al., 2012; Kumar and Saxena, 2011). Several factors may control the mobility of fluorine in natural waters. Many authors have described fluorite dissolution, enhanced by calcite precipitation, as one of the important mechanisms of F^- release to waters in equilibrium with calcite (Currell et al., 2011; Desbarats, 2009). The dynamics of F^- ions may also be controlled by adsorption/de-sorption onto different mineral surfaces under neutral to acidic conditions (Kim et al., 2012; Omueti and Jones, 1977)

In Birbhum district, (4545 km^2) about 52,563 population distributed over 78 villages/hamlets in seven blocks namely Khoyrasol, Nalhati-I, Rajnagar, Rampurhat-I, Suri-II, Mayureswer-I and Saithia are affected by fluorosis, due to high F^- in groundwater. In these blocks, groundwater occurs in different geologic formations viz. fractured granite, basalt and alluvial aquifers at a depth of 50 to 80 m depth, and in Gondwana formation at a depth of 30 m. F^- concentration in these formations was reported from 1.5 to 17.9 mg/L (Mehta and Srivastava, 2009). Although some researchers have focused on the aspect of health assessment (Mondal et al., 2012) and quantitative accumulation of F^- in crops (Gupta and Banerjee, 2011) irrigated by F^- contaminated irrigation water, only very few works focused on the

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genesis of fluoride particularly in Quaternary aquifers. Gupta et al. (2006) reported high F^- concentration in some artesian waters of Nasipur-I block and concluded that the intertrappean sediments originally having F^- rich minerals within the Rajmahal volcanics dissolved in the entrapped water due to favourable physico-chemical conditions. Another mechanism suggested was highly soluble villiaumite (NaF) within the volcanic traps may leach in to the entrapped water and dissolved locally in certain pockets.

The present study aims to characterize the hydrogeochemical properties of groundwater in association with geochemistry of aquifer material, to understand the origin and mobilisation mechanism of F^- in Quaternary aquifer. Apart from that, other tools like, vertical resistivity soundings and drilling of holes helped to assess the extent and thickness of aquifer and to collect the aquifer material. Stable isotope data in

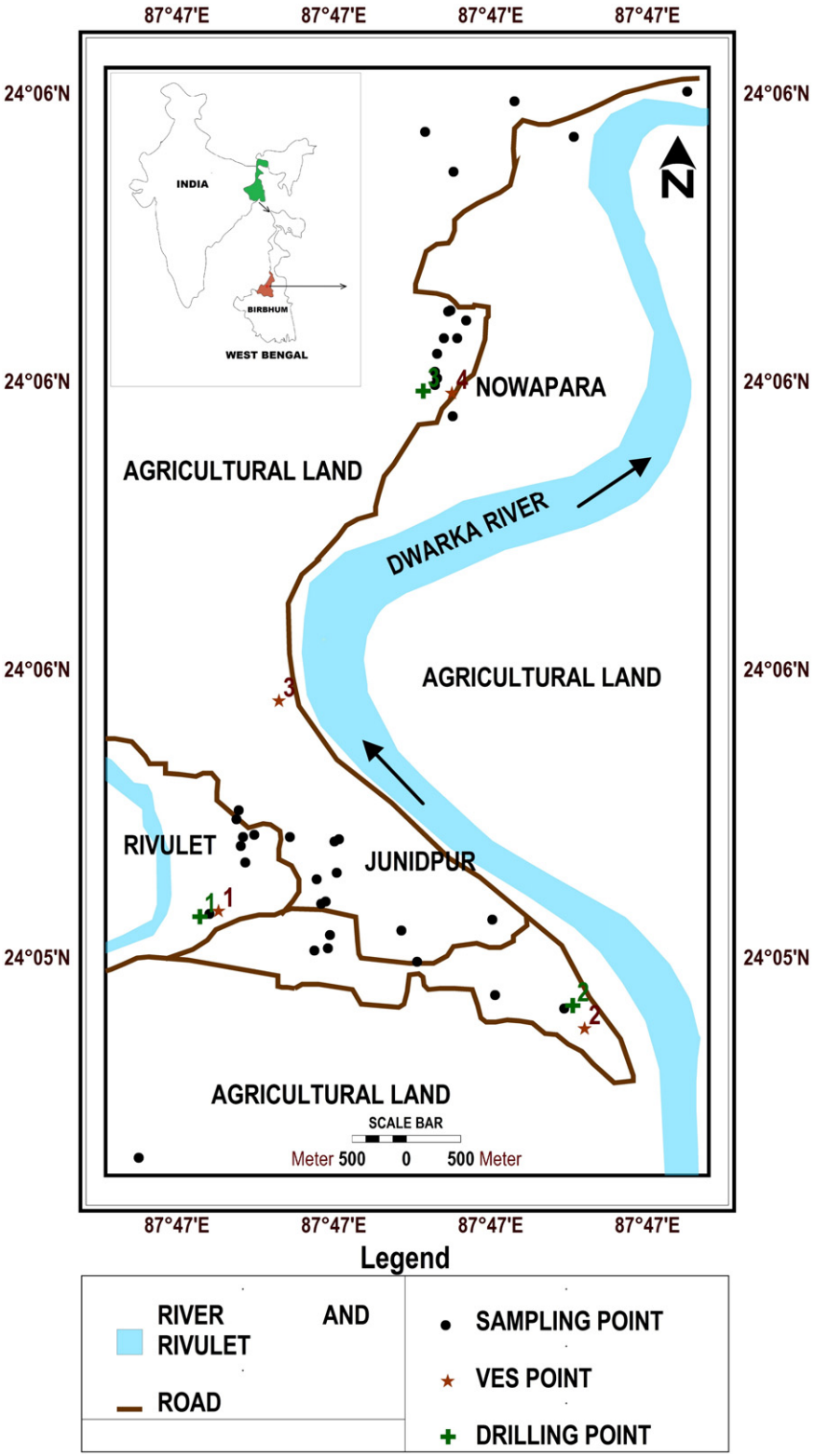

Fig. 1. Location of study area indicating sampling points, VES points and borehole points.