Chemosphere 168 (2017) 817–824

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Fluoride enrichment in an alluvial aquifer with its subsequent effect on human health in Birbhum district, West Bengal, India

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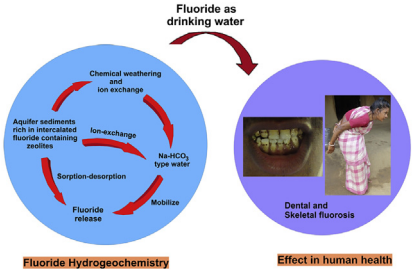
HIGHLIGHTS

- High F^- occurrences in zeolitic-rich aquifer sediments.
- Ion-exchange mechanism is the major hydrogeochemical process.
- Langmuir and Temkin isotherm are the best fitted isotherm.
- Women of >30 years of age have more osteoporosis.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 15 April 2016
Received in revised form
5 October 2016
Accepted 30 October 2016
Available online 9 November 2016

Handling Editor: Martine Leermakers

Keywords:
F^- geochemistry
Zeolite
TF index
Bone mineral density

ABSTRACT

This research work primarily deals with the geochemistry and genesis of fluoride (F^-) in an alluvial aquifer with an emphasis on prevalence of dental and skeletal fluorosis among the endemic population. Hydrogeochemical outcomes reveal that chemical weathering and ion-exchange phenomena are the two dominant processes that make study area groundwater into Na–HCO_3 water type. Presence of intercalated zeolite rich sediments (F_{Total} 412–446 mg/kg) having higher ion-exchange capacity (120–125 meq/100 g) within the aquifer is the source and mobilizing factors of F^- in groundwater respectively. Laboratory experiment further justifies higher desorption potential of aquifer sediments at the groundwater pH of 6.5–7.5. Health survey reveals that out of 235 studied population 60% suffer from dental fluorosis while females >30 years of age became exposed early to osteoporosis disease.

1. Introduction

Fluorine occurs mainly as free F^- ion in natural waters, although some F^- complexes do exist under specific conditions. Groundwater in many developed and developing regions such as United Kingdom, and the Western United States, East and North Africa, Korean Peninsula, India and China has elevated F^- concentrations (Edmunds and Smedley, 2005; Zhu et al., 2007; Reddy et al., 2010). For the F^- in groundwater, common natural sources are the dissolution of minerals, such as fluorapatite, amphiboles (*e.g.*, hornblende, tremolite) and some mica weathered from igneous and sedimentary rocks (Datta et al., 1996). Fluoride dynamics in igneous terrain is well-known (Edmunds and Smedley, 2005; Shaji et al., 2007; Reddy et al., 2010) rather than alluvial aquifers (Guo et al., 2010; Kumar and Saxena, 2011; Kim et al., 2012). The dynamics of F^- ions may also be controlled by its different sorption

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http://dx.doi.org/10.1016/j.chemosphere.2016.10.130
0045-6535/

behaviour onto different mineral surfaces under neutral to acidic conditions (Omueti and Jones, 1977; Kim et al., 2012).

Fluoride can be naturally occurring but is known to cause a great deal of health hazards for humans when exposed in excess. It is now an established fact that F^- ingestion over a long period of time can affect the structure and function of tissues, organs and systems resulting in a variety of clinical manifestations. Research shows that severe dental and crippling skeletal fluorosis effects are but some of the manifestations of toxicity.

In Birbhum district (4545 km^2) about 53 thousand people spread over 78 habitations in seven blocks (district subdivision) namely Khoyrasol, Nalhati-I, Rajnagar, Suri-II, Mayureswer-I, Rampurhat-I and Saithia are affected by F^- contaminated groundwater. Most of these blocks have F^- above permissible limits (1.5–17.9 mg/L) where groundwater is extracted from fractured granite, basalt and alluvium aquifer lie at a depth of 30–80 m (Central Groundwater Board, 1985). Two adjacent villages (total area 1.5 km^2) namely Nowapara (24° 06′ 18″N and 87° 47′ 02″E) and Junidpur (24° 06′ 07.5″N and 87° 46′ 54.7″E) of Rampurhat-I block, Birbhum district were selected for the present study (Fig. 1). Both the villages lie at the discharge zone of Dwarka river basin and fluorosis has been reported for past 6–8 years.

So far very limited research works are reported from the study area (Gupta et al., 2006; Mondal et al., 2014) in the field of hydrogeochemistry and comprehensive research work addressing both the chemistry of groundwater and aquifer sediments in deciphering genesis and mobilization of F^- in the alluvial aquifer is completely lacking. Apart from this prevalence of dental and skeletal fluorosis has also been addressed to means of Thylstrup and Fejerskov (TF) index (after Thylstrup and Fejerskov, 1978) and simple scoring approach respectively.

2. Materials and methods

2.1. Hydrogeological and geomorphological setting of the study area

The present study area is basically situated in the flood plain of the Dwarka River basin. The river originates from Chotonagpur plateau in Jharkhand state and flows in the direction of south-west to north-east. The major rock types in the catchment area are granites and Rajmahal volcanics whereas the discharge zone is mainly dominated by alluvial sediments. The exposed recent alluvium consists of yellow coloured sand and clay and poor in

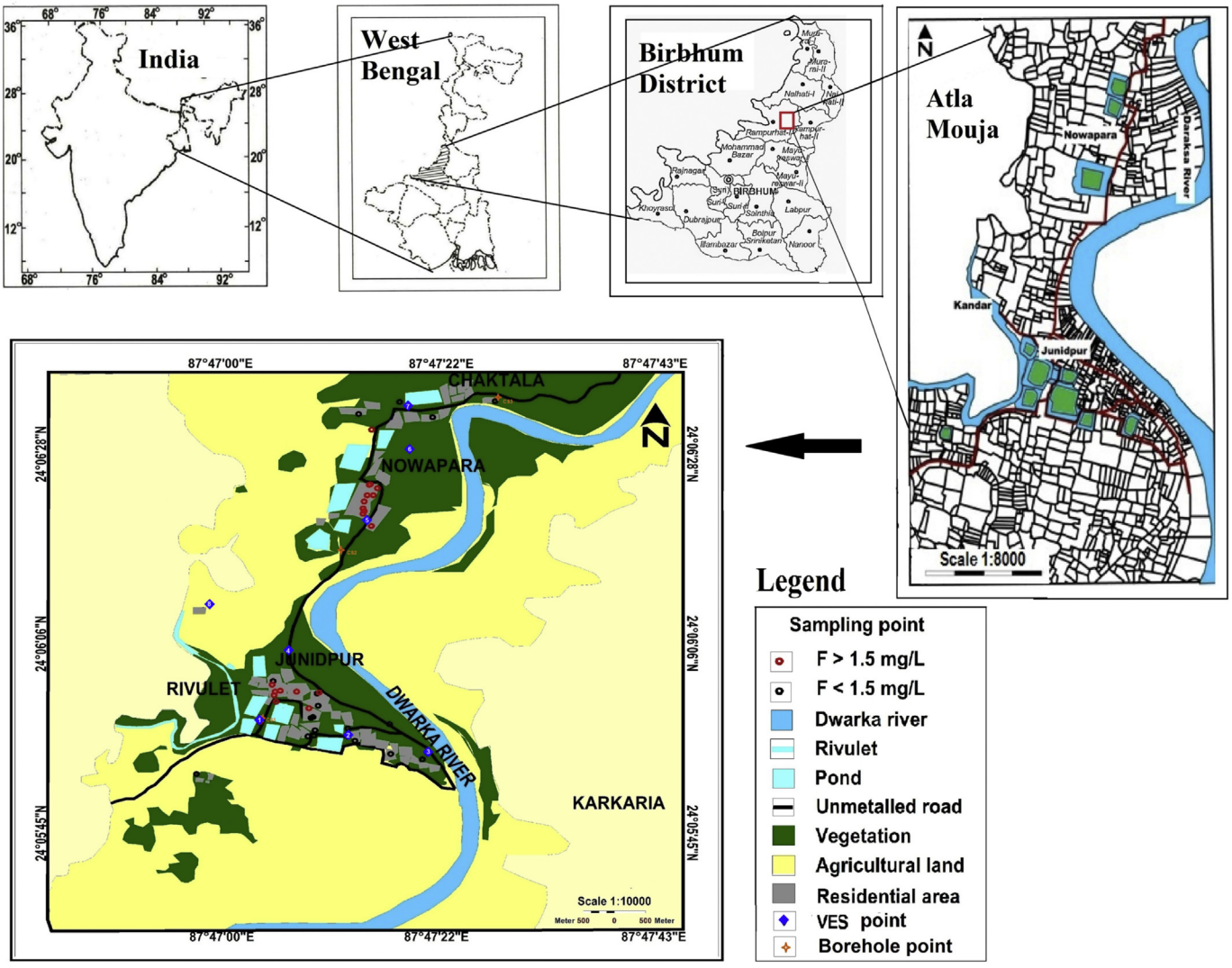

Fig. 1. Location of study area indicating sampling points, VES points and borehole points.