JOURNAL GEOLOGICAL SOCIETY OF INDIA
Vol.88, September 2016, pp.350-356

Geochemical Processes Controlling Fluoride-bearing Groundwater in the Granitic Aquifer of a Semi-arid Region

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Abstract: The aim of the present study is to identify the geochemical processes responsible for higher fluoride (F^-) content in the groundwater of the Yellareddigudem watershed located in Nalgonda district, Andhra Pradesh. The basement rocks in the study area comprise mainly of granites (pink and grey varieties), which contain F-bearing minerals (fluorite, biotite and hornblende). The results of the study area suggest that the groundwater is characterized by Na^+: HCO facies. The F^- content varies from 0.42 to 7.50 mg/L. In about 68% of the collected groundwater samples, the concentration of F^- exceeds the national drinking water quality limit of 1.5 mg/L. The weathering of the granitic rocks causes the release of Na^+ and HCO ions, which increase the solubility of ions. Ion exchange between Na^+ and Ca^{2+}, and precipitation of $CaCO_3$ reduce the activity of Ca^{2+}. This favours dissolution of CaF_2 from the F-bearing minerals present in the host rocks, leading to a higher concentration of F^- in the groundwater. The study further suggests that the spatial variation in the F^- content appears to be caused by difference in the relative occurrence of F-bearing minerals, the degree of rock-weathering and fracturing, the residence time of water in the aquifer materials and the associated geochemical processes. The study emphasizes the need for appropriate management measures to mitigate the effect of higher F groundwater on human health.

Keywords: Fluoride, Groundwater, Granite rocks, Watershed, Semi-arid region, Andhra Pradesh.

INTRODUCTION

Fluoride (F^-) is essential in small quantity for prevention of dental caries. However, its higher content (> 1.50 mg/L) in drinking water causes fluorosis (BIS, 2012). High F^- groundwater has been reported in different parts of the world, especially in arid and semi-arid climatic regions (Ayoob and Gupta, 2006). Granite rocks contain a relative abundance of F^--bearing minerals (apatite, fluorite, biotite and hornblende). They are the main source of F^- in groundwater (Ramesham and Rajagopalan, 1985; Ramamohan Rao et al., 1993; Apambire et al., 1997; Subba Rao and John Devadas, 2003; Edmunds and Smedley, 2005; Jacks et al., 2005; Ayoob and Gupta, 2006; Reddy et al., 2010; Brindha et al., 2011). Groundwater evaporation, residence time in the host rocks and agro-chemicals used for irrigation are the important factors involved for higher concentration of F^- in groundwater (Handa, 1975; Hem, 1991; Genxu and Guodong, 2001; Jacks et al., 2005; Reddy et al., 2010; Brindha et al., 2011; Subba Rao et al., 2013).

Nalgonda district is one of the semi-arid regions of Andhra Pradesh (Fig. 1). The first case of fluorosis in the district was reported in 1968 by Siddiqui (1968). A study of F^--bearing minerals in the granite rocks and of geochemistry of F^- in groundwater of the district was conducted by Natarajan and Mohan Rao (1974) and Natarajan and Murthy (1974). A comprehensive study of F^- concentration in the soils, rocks and groundwater in the district was carried out by Ramamohan Rao et al. (1993), Reddy et al. (2010) and Brindha et al. (2011). They reported that the F^- content is variable in groundwater, which means that geochemical factors responsible for higher F^- content in groundwater are not uniform. Once the controlling factors are known, it can be possible to take the appropriate management measures to mitigate the effect of elevated F^- groundwater on human health. Therefore, the focus of the present paper is to assess the geochemical processes involved for higher F^- content in the groundwater in the granite aquifer of a semi-arid region.

0016-7622/2016-88-3-350/$ 1.00