Sustainability of Water Quality and Ecology 6 (2015) 57–74

Contents lists available at ScienceDirect

Sustainability of Water Quality and Ecology

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

Evaluation of groundwater quality in the Chotanagpur plateau region of the Subarnarekha river basin, Jharkhand State, India

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ARTICLE INFO

Article history:
Received 4 December 2014
Received in revised form 7 May 2015
Accepted 4 June 2015
Available online 5 June 2015

Keywords:
Groundwater
Hydrogeochemistry
Water quality
Synthetic pollution index
Heavy metals

ABSTRACT

Suitability study of groundwater for domestic and irrigation purposes was carried out in the middle Subarnarekha river basin, Jharkhand. Collected samples were analysed for physicochemical parameters such as conductivity, total dissolved solids (TDS), pH, and heavy metals. After the physicochemical analysis groundwater samples were categorised for simplicity, accordingly, it shows that 52.6% samples fall in $Ca\text{-}Cl_2$, 33.3% in $Ca\text{-}HCO_3$, 10.5% in $Ca\text{-}SO_4$, and 1.7% samples in $Mg\text{-}HCO_3$ and rest were Na-Cl type. Interpretation of hydro-geochemical data suggests that leaching of ions followed by weathering and anthropogenic impact (mainly mining and agricultural activities) control the chemistry of groundwater in the study area. The TDS concentration at Govindpur site varies from 2677 mg L^{-1} in the pre-monsoon to 2545 mg L^{-1} in the post-monsoon season that is higher than the BIS (2004-05) maximum permissible limit (2000 mg L^{-1}). The elevated concentration of NO_3^- was identified at Govindpur, Hatia Bridge, Kandra, Musabani, Saraikela, Mango and Tatanagar. The higher NO_3^- concentration was due to the action of leaching and anthropogenic activities. At most of sampling locations, the concentration of Cd, Pb, and Ni were found higher than the prescribed limits defined by BIS and WHO. Groundwater suitability for drinking purpose was also evaluated by the synthetic pollution index (SPI), it suggests that 74%, 95%, and 21% samples fall in seriously polluted category during pre-monsoon, monsoon, and post-monsoon season, respectively. The calculated values of SAR, Na%, RSC, PI, and MH have shown that except at few locations, most of groundwater samples are suitable for irrigation purposes.

1. Introduction

Groundwater is a natural freshwater resource and its sustainable utilisation is one of biggest challenges to policy makers around the world. Generally, water supplies from groundwater are free from suspended and organic impurities due to natural filtration through soils and sediments (Karanth, 1989). Geochemical processes, regional geology and land use pattern are major factors for controlling groundwater chemistry (Matthess, 1982; Kumar et al., 2006; Liu et al., 2008; Zhu and

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http://dx.doi.org/10.1016/j.swaqe.2015.06.001
2212-6139/

Schwartz, 2011; Rajesh et al., 2012). The evaporation and irrigation return flow also influence major ion chemistry of groundwater (Stigtera et al., 1998; Hudak, 2000; Guo and Wang, 2004; Rajmohan and Elango, 2006).

In response to developmental activities, groundwater availability as well as quality is deteriorating at a faster rate. Groundwater flow and storage in hard rock regions have always been a major issue for researchers, general public and water managers (De Silva and Weatherhead, 1997; Ballukraya and Sakthivadivel, 2002; Negrel et al., 2011), either with respect to water quantity (Gupta and Singh, 1988) or water quality (Robins and Smedley, 1994). The limitation of groundwater resource and aquifers (Singhal et al., 1988) and their long-term sustainability (Foster et al., 2002) is also a major issue. Many researchers have assessed groundwater quality in various parts of India (Prasad, 1998; Kaul et al., 1999; Abbasi et al., 2002; Jagdap et al., 2002; Gupta and Deshpande, 2004; Khaiwal and Garg, 2006; Prakash and Somashekar, 2006; Singh and Chandel, 2006; Shivran et al., 2006; Bishnoi and Arora, 2007; Gupta et al., 2008; Srinivasamoorthy et al., 2011; Singh et al., 2009, 2012, 2013a,b, 2015; Kumar et al., 2014). Chourasia and Tellam (1992) have reported that groundwater of irrigated areas have higher ionic concentration as compared to non-irrigated areas in hard rock terrain of central India. Many studies have found that the deterioration of groundwater quality is also due to over withdrawal (Kamra et al., 2002; Singh et al., 2002; Négrel et al., 2007) resulting in the higher salinity, fluoride, nitrate, iron and other heavy metals in groundwater. Further, extensive application of pesticides and fertilizers in agricultural fields, inadequate sewage treatment system (Gautam et al., 2013), and mixing of untreated industrial and municipal effluents with groundwater (Wen et al., 2005; Rao et al., 1997; Vasanthavigar et al., 2012), result in decline of groundwater quality. Giri et al. (2010) have assessed the concentration of heavy metals (Fe, Mn, Zn, Pb, Cu, and Ni) in the groundwater of East Singhbhum region and found that Fe and Mn concentrations were higher than permissible limit. Health risks due to intake of heavy metals through the ingestion of groundwater around uranium mining areas in Jharkhand were also reported by Giri et al. (2012).

The main objective of this study is to evaluate the suitability of groundwater specifically for drinking and irrigation purposes by analysing the collected samples and through irrigation indices and also to assess the quality with reference to heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) contamination and their human health effects. Further we have computed the irrigation indices and synthetic pollution index (SPI) and categorised water samples into different groups for proper management of groundwater resources for drinking and irrigation purposes.

2. Study area

The rainfed Subarnarekha River is one of the major river of the Chotanagpur plateau, in the state of Jharkhand, India. It originates from the Nagri village of Ranchi plateau (23.4°N, 85.4°E), situated at 756 m above sea level (Fig. 1a and b), flows through state of Jharkhand, West Bengal and Orissa with a total length of 470 km and finally falls into the Bay of Bengal. The total catchment area of the Subarnarekha river is 18,950 km^2 and spread in Jharkhand (13,590 km^2), Orissa (3200 km^2) and West Bengal (2160 km^2) (Rao, 1995). The dominant land use/land cover includes forest, agriculture, industrial areas and mining activities.

2.1. Physiography and climate

The Subarnarekha river basin is characterised by a region of varied physiography ranging from steep hill masses to flat coastal plain through a series of dissected plateaus and sloping plains. Six physiographic divisions have been recognised in the Subarnarekha basin, which are Ranchi plateau, escarpments and plateau slopes, uplands, central plains, intervening hill ranges and coastal plain (Mukhopadhyay, 1980).

The climate of the basin is dry sub-humid to humid sub-arid type. The cold winter season (November to February) temperature is 10–20 °C. The hot summer (March to mid-June) temperature is 37–20 °C. The southwest monsoon brings rainfall with an average annual rainfall of 1400 mm. The 82.1% of 1400 mm total rainfall is received during the months of June to September and remaining 17.9% in rest of the months.

2.2. Geology of the Subarnarekha river basin

The general geology of the basin is a part of Precambrian terrain of the Singhbhum craton (Fig. 2). The prominent 200 km long copper belt thrust zone of Singhbhum separates the Precambrian basement of the region into two distinct provinces as the Singhbhum-Orissa iron ore province on the south and the Satpura province on the north. The craton consists of eight principal lithological associations (Ramakrishnan and Vaidyanadhan, 2008) such as: (i) Singhbhum granite with enclaves of older Metamorphic Tonalite Gneiss (OMTG) and Older Metamorphic Group (OMG) of sediments and volcanics, (ii) basins of Banded iron formation (BIF) around the Singhbhum granite, (iii) Volcanic basins, loosely termed as greenstone belts, (iv) Flysch-like sediments and volcanics of North Singhbhum orogeny, (v) Mafic dyke swarms, (vi) Kolhan basin, (vii) newer tertiary and (viii) alluvium. The detailed chronostratigraphic succession can be found in Sarkar and Saha (1977) and Saha (1994). About 83% area of the Subarnarekha basin is occupied by hard rocks like granite-schists, mica schists, gabbro, etc., and remaining 17% is underlain by soft rocks represented by Tertiary grits and gravels and Quaternary alluvial sediments. It is underlain by folded and fractured Precambrian metasediments, mainly mica schists, quartzite and hornblende schists