Groundwater Quality and Hydrogeochemical Characterization of Khetri Copper Mining Region, India

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Abstract
The impact of copper mine on groundwater quality in the semi-arid region is evaluated, and also characterized for hydrogeochemical processes. Groundwater samples (post monsoon and pre monsoon) from Khetri copper mine region of Rajasthan, India were studied. In majority of groundwater samples, the values of analyzed parameters such as EC, Ca^{2+}, Mg^{2+}, Na^{+}, HCO_3^{-} and Cl^{-} exceed the WHO (2011) and Bureau of Indian Standards (2012) permissible limits. Higher concentrations of ions were observed near the mining activities (mines, tailings, overburden rocks and abandoned mine) and in the downstream of groundwater flow from mines suggesting significant influence of mines on water quality. High concentration of major ions is attributed to oxidation of sulfides or acid mine drainage (AMD). The Gibbs plot for cations and anions as a function of TDS indicates the evolution of groundwater from rock-water interaction in both seasons. Thus, increased major ions concentration is due to dissolution of minerals by AMD.
Keywords: Groundwater quality; Hydrogeochemistry; Anthropogenic processes; Khetri copper mines

1. Introduction

The northwestern part of India, particularly Khetri region is known for copper mines and it is highly enriched in sulphides. The region is also known for high rate of depletion of groundwater. Sulphides reacts fastest followed by carbonates and silicates (Sherlock et al. 1995). Hence, the sites near metallic mines are more susceptible to dissolution of minerals.

Present study was taken up to assess the impact of mines on groundwater quality and hydrogeochemical characterization in Khetri copper mining region, India. For this, groundwater sampling was carried out in the neighbouring areas of mines, overburden rocks, tailing dam and abandoned mine. The metallic mining can adversely impact the hydrogeochemical characteristics of the region. Thus, the characterization of hydrogeochemistry of groundwater in the mining region is important for planning and implementing the waste management policies.

2. Materials and Methods

Groundwater samples were collected from the periphery of mining areas. A total of 17 and 22 water samples were collected in the months of March (pre monsoon) and October (post monsoon), 2015 respectively. Anions namely HCO_3^{-}, Cl^{-}, SO_4^{2-} & NO_3^{-} were analysed following APHA (2012) protocol. Cations such as Na^{+}, Mg^{2+}, K^{+} & Ca^{2+} using Atomic Absorption Spectrophotometer (ThermoScientific M series) using air-acetylene gas as a fuel.

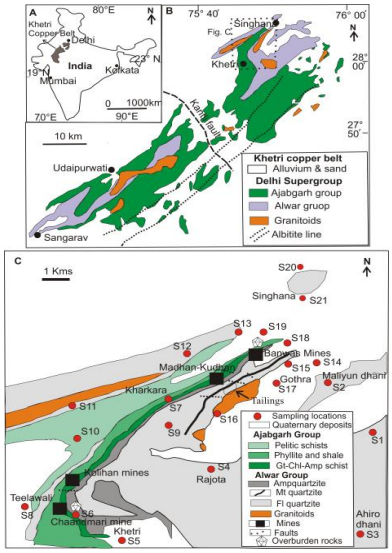

Figure 1. A) Map of India B) Geology of Khetri copper belt after Chen et al. 2015 C**)** Distribution of groundwater sampling locations.

3. Results

In majority of samples concentration of cations and anions exceed the permissible limits prescribed by WHO (2011) and BIS (2012) (Table 1). It indicates high contamination and unsuitability of groundawater for drinking purposes at Khetri.

Relatively higher concentrations of major ions are found in the close vicinity of mining area (S13, S15, S16, S17, S18 & S19). Mining has been going on in the hilly region of the study area and mining waste is also being dumped in the hills. The groundwater flow is from hills (stretching southwest-northeast) to towards northern and eastern parts, the sampling location falling in the eastern (S4, S16, S17, S18 & S19) and northern (S20 & S21) direction shows higher concentration of major ions compared to the western sampling locations (S7, S8, S9, S10 & S11).

Thus, the presence of high concentration of ions in the vicinity and downstream direction of groundwater flow from Cu mines is attributed to dissolution of efflorescent salts and minerals due to mining activities.

In the semi-arid region, seasonal variation of major ion is important to study as fluctuating groundwater level have significant influence on major ion concentration (Vasanthavigar et al. 2012). The infiltrating water in rainy season leads to leaching of salts and minerals. The seasonal variation in concentration of major ion further indicates that concentration of major ion in groundwater is highly influenced by external physiochemical factors such as infiltration of rainwater, acidic sludge seepage or other anthropogenic activities in short duration.

Table 1. Comparison of major ion concentrations of groundwater from Khetri copper mine region with WHO and BIS standards (all concentrations are in mg/L)

Parameters	WHO (2011) Desirable	BIS Desirable Limit	BIS Permissible Limit	No. of samples exceeds WHO limit		No. of samples exceeds the BIS limit			
						Pre-Monsoon(n=17)		Post-Monsoon (n=22)	
				Pre (n=17)	Post (n=22)	Desirable	Permissible	Desirable	Permissible
pH	6.5-8.5	6.5-8.5	-	1	1	1	-	1	-
Ec	750	-	-	15	20	-	-	-	-
Alkalinity	-	200	600	-	-	14	1	16	1
TDS	600	500	2000	15	19	12	3	16	3
Ca^{2+}	75	75	200	12	17	6	6	11	6
Mg^{2+}	50	30	100	9	21	10	6	7	14
Na^{+}	200	-	-	6	13	-	-	-	-
K^{+}	12	-	-	6	5	-	-	-	-
HCO_3^{-}	120	-	-	16	21				
SO_4^{2-}	250	200	400	0	1	1	-	7	-
NO_3^{-}	10	45	100	12	15	5	7	8	7
Cl^{-}	250	250	1000	14	8	13	2	8	-

During post monsoon season, SO_4^{2-} has a positive correlation with Ca^{2+} (0.74), Mg^{2+} (0.76) and Na^{+} (0.72) indicating the leaching of sulphides during rainy season which could have promoted the dissolution of silicates and releasing these cations. The Gibbs diagram (Gibbs 1970) shows that most of the geochemical data falls in the rock weathering dominance zone for both the seasons (Fig. 2a & b). Thus, observed significant corrletaion among ions and gibbs plots indicates the silicate weathering or rock-water interaction as a major source for dissolved ions in the groundwater.

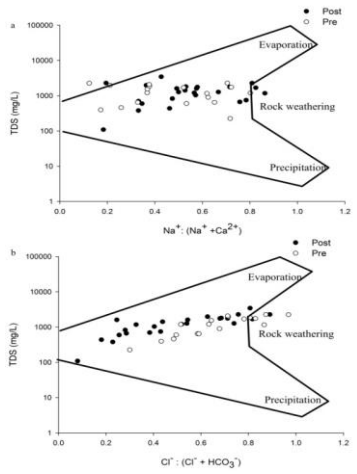

Figure 2. Gibbs plots for pre and post monsoon

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