Journal of Hazardous Materials 160 (2008) 535–547

Contents lists available at ScienceDirect

Journal of Hazardous Materials

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

Impact assessment of chromite mining on groundwater through simulation modeling study in Sukinda chromite mining area, Orissa, India

Ratnakar Dhakate*, V.S. Singh, G.K. Hodlur

National Geophysical Research Institute, Hyderabad 500007, Andhra Pradesh, India

ARTICLE INFO

Article history:
Received 27 August 2007
Received in revised form 27 December 2007
Accepted 9 March 2008
Available online 20 March 2008

Keywords:
Migration
Geophysical
Hydrogeological
Groundwater modeling

ABSTRACT

The pre-Cambrian chromites ore deposits in Sukinda valley, Jajpur District, Orissa, India, are well known for chromite ore deposits. The exploitation of the ore is carried out through open cast mining method since the last few decades. In the process, the overburden and ore dumps are stored on ground surface, where leaching of chromite and other toxic element takes place particularly during monsoon seasons. This leachate may cause threat to groundwater in the vicinity. An integrated approach has been adopted to evaluate possibility of pollution due to mine seepage and leachate migration on groundwater regime. The approach involves geophysical, hydrogeological, hydro-chemical and aquifer modeling studies. The investigation has the significance as many habitats surround the mining area facing groundwater problems.

1. Introduction

In the process of development, mining is one of the core industries contributing, knowingly or unknowingly, towards the deterioration of the environment in terms of air, water and land pollution [13]. To achieve sustainable development, environmental protection elements should be introduced at the planning stage of the mining project. India is endowed with a wide range of mineral reserves. In the country there are approximately 9906 mining leases spread over an area of 7453 km^2 covering 55 minerals other than fuel. Metal mining posses problems to the water environment by discharging mine water from underground and open pit mines [14,23]. Leachate water and runoff water from overburden/waste rock dumps also contaminate nearby water streams [35]. The potential impacts from leaching operations on the environment are most likely to be experienced as changes to surface and groundwater quality. The quality of the mine water depends upon various factors including physical characteristics of the ore, net acid generating potential, groundwater characteristics, back fill practice, mining practice and age of mine etc., and aquifer characteristics.

Mine water can frequently have quality problems, primarily due to the alteration of equilibrium in underground water and the formation of Acid Rock Drainage (ARD in metal mine or sulfides ores). This in turn creates a problem of dissolving heavy metals and carrying suspended particles of lithological materials and affected the surface and groundwater quality. ARD has been recognized as one of the largest environmental problem facing the metal mining sector [7,27]. ARD and associated heavy metal contamination is caused by natural oxidation taking place when minerals are exposed to air and water. Sulfide oxidizing bacteria play an important role in the formation of Acid Mine Drainage (AMD) [22,34], and these can be control by wetlands [22], while waste rock and tailings are the most significant sources of acid drainage, other mine components such as open pit surfaces, underground workings, stockpiles and concentrate stage and loading areas are also potential sources of AMD. Metal mining especially Pb-Zn mine severely contaminates groundwater quality [12]. Metal contamination due to mining and associated activities at Zawar zinc mine, Rajasthan, India also reported by [27].

In arid or semi-arid environment where surface water is limited, the most affected environmental component often affected is groundwater. The principle pathways by which leach contaminants can enter into groundwater are leakage or spills from storage ponds, leach pad liners, subsequent leaching to groundwater, storm water run-on/off uncontrolled leaching from heaps and dumps following closer [23].

Level of pollution due to chromite ore mining has also been reported to be severe [25]. Tailing dams seepage as well as effluent discharged from concentration and screening plants also plays an important role in groundwater pollution. The surrounding soil and plants are also reported to be enriched in chromium content around the chromium rich ultramafic terrains in Pakistan [21], these ultramafic soils is also helpful in oxidation of chromium [9]. Previous studies have shown that a high degree of heavy metal contamina-

* Corresponding author. Tel.: +91 40 23434700; fax: +91 40 27171564.
E-mail address: dhakate_ratnakar@yahoo.com (R. Dhakate).

0304-3894/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.jhazmat.2008.03.053

tion in soil and plants has occurred in many places in the world, which could be related to the occurrence of ore deposits [14].

The Sukinda valley in Jajpur District, Orissa, is known for its deposit of chromites ore producing nearly 8% of chromite ore in India [18]. There are number of open cast mines in the area. During the process of mining the waste rock materials as well as chromite ores are dumped on ground surface. In Sukinda mining area around 7.6 million tonnes of solid waste have been generated in the form of rejected minerals, overburden material/waste rock and sub grade ore [18]. The mine seepage water is also discharged into the nearby drainage and Damasal Nala, which is often being used as source of water by adjoining villages.

Chromium exists in the environment in either the trivalent Cr(III), or hexavalent Cr(VI) form, Cr(III) is considered to be essential to mammals for the maintenance of glucose, lipid, and protein metabolism. On the other hand, Cr(VI) is known to have an adverse effect on the lungs, liver and kidneys [36]. Concentration and mobility in groundwater are directly related to the dominant valence state in which chromium occurs, which in turn is controlled by chemical and physical characteristics of the groundwater environment. Chromium in groundwater is influenced primarily by oxidation–reduction potential (Eh) and pH [17]. At constant pH, Cr(VI) species predominate in solution under high Eh (oxidizing) conditions, whereas Cr(III) species predominate under lower Eh conditions. Cr(VI) species can be readily reduced to Cr(III) in the presence of naturally occurring organic matter [5,6,34], ferrous [Fe (II)] iron [11,19,31] and sulfide [31], these constituents act as reducing agent in aquifer sediments [4]. Cr(VI) can also be reduced by *Thiobacillus ferrooxidans* [28,33], by using trimanganese tetroxide, and by manganese (III) oxide [30].

The main source of potable water in the area is groundwater, which is tapped by shallow dug wells, and deep bore wells. In order

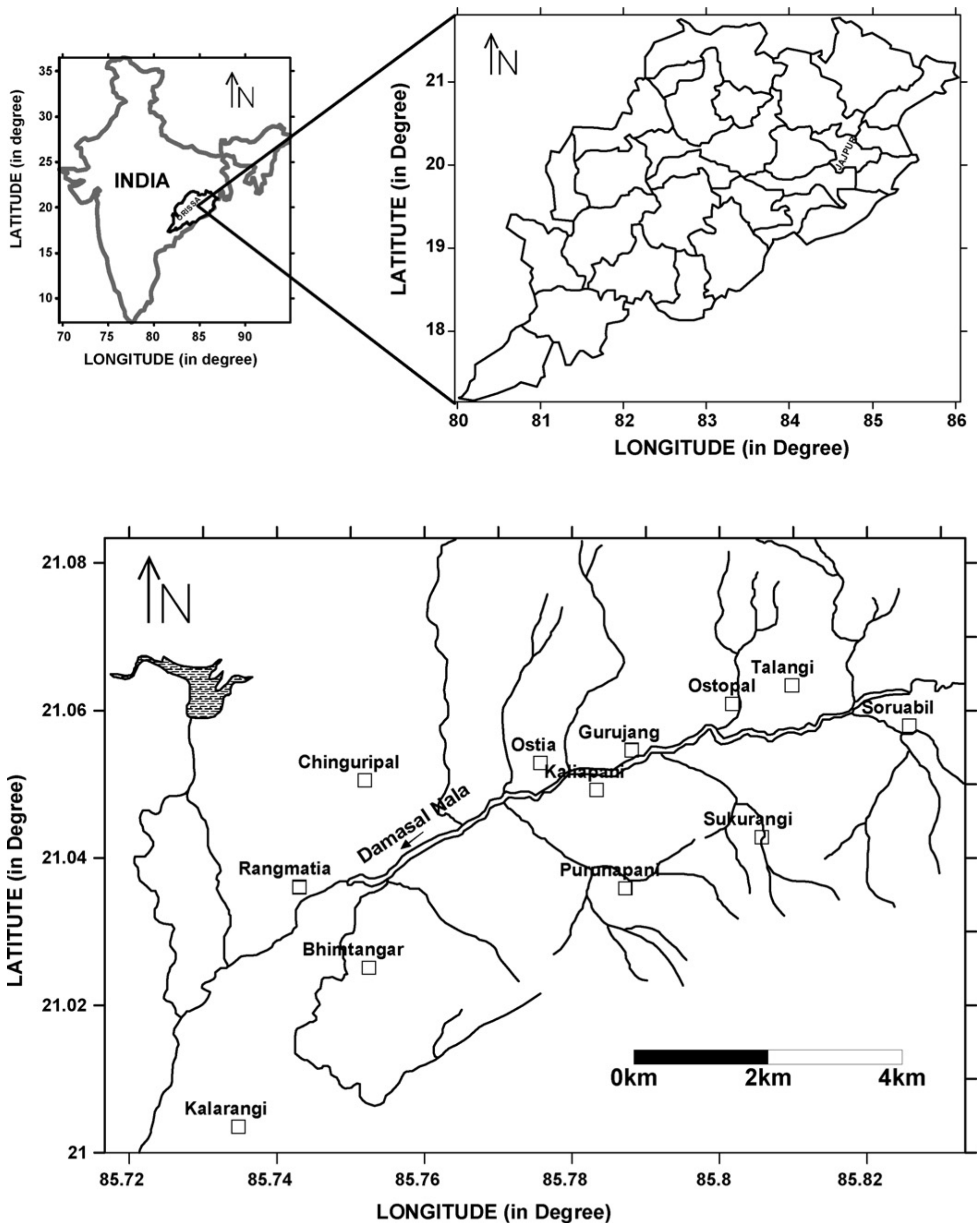

Fig. 1. Key map of the study area.