Available online at www.sciencedirect.com
ScienceDirect
Physics and Chemistry of the Earth 31 (2006) 789–796
PHYSICS and CHEMISTRY of the EARTH
www.elsevier.com/locate/pce

Influence of the Trojan Nickel Mine on surface water quality, Mazowe valley, Zimbabwe: Runoff chemistry and acid generation potential of waste rock

Keretia Lupankwa [a], David Love [a,b,*], Benjamin Mapani [c], Stephen Mseka [d], Maideyi Meck [a]

[a] Department of Geology, University of Zimbabwe, P.O. Box MP167, Mt. Pleasant, Harare, Zimbabwe
[b] WaterNet, P.O. Box MP600, Mt. Pleasant, Harare, Zimbabwe
[c] Geology Department, University of Namibia, P. Bag 13301, Windhoek, Namibia
[d] Bindura Nickel Corporation, P.O. Box 35, Bindura, Zimbabwe

Abstract

The impacts of mining on the environment depend on the nature of the ore body, the type of mining and the size of operation. The focus of this study is on Trojan Nickel Mine which is located 90 km north of Harare, Zimbabwe. It produces nickel from iron, iron–nickel and copper–nickel sulphides and disposes of waste rock in a rock dump. Surface water samples were taken at 11 points selected from a stream which drains the rock dump, a stream carrying underground water and the river into which these streams discharge. Samples were analysed for metals using atomic absorption spectrometry, for sulphates by gravitation and for carbonates and bicarbonates by back titration. Ninteen rock samples were collected from the dump and static tests were performed using the Sobek acid base accounting method. The results show that near neutral runoff (pH 7.0–8.5) with high concentrations of sulphate (over 100 mg/L) and some metals (Pb > 1.0 mg/L and Ni > 0.2 mg/L) emanates from the dump. This suggests that acid mine drainage is buffered in the dump (probably by carbonates). This is supported by the static tests, which show that the fine fraction of dump material neutralises acid. Runoff from the dump flows into a pond. Concentrations of sulphates and metals decrease after the dump runoff enters the pond, but sufficient remains to increase levels of calcium, sulphate, bicarbonate, iron and lead in the Pote River. The drop in concentrations at the pond indicates that the settling process has a positive effect on water quality. This could be enhanced by treating the pond water to raise pH, thus precipitating out metals and decreasing their concentrations in water draining from the pond.

Keywords: Water quality; Mine dump; Environmental geochemistry; Mined rock piles; Acid mine drainage; Mazowe valley

1. Introduction

1.1. Base metal mining and acid mine drainage

Open pit and underground mining involves the excavation of large quantities of rock in order to extract the desired mineral ore. The waste rock, which often contains sulphides and other metal-bearing minerals, is usually stored above the ground in large, free draining piles, referred to as waste rock dumps or mined rock piles. When the sulphides become exposed to air and water, they are oxidised, leading to a reduction in pH, destruction of the bicarbonate buffering system in the water, and increases in concentrations of soluble and particulate metals (Ravengai et al., 2004). The oxidation of the relatively common iron sulphide minerals (mainly pyrite (FeS_2) and pyrrhotite (FeS)) in the presence of catalysing bacteria, such as *Thiobaccilus ferroxidans*, results in a metal-rich water termed

* Corresponding author. Address: WaterNet, P.O. Box MP600, Mt. Pleasant, Harare, Zimbabwe. Tel.: +263 4336725/838110; fax: +263 4336740/838253.
E-mail addresses: davidlove@science.uz.ac.zw, d.love@cgiar.org (D. Love).

1474-7065/$ - see front matter
doi:10.1016/j.pce.2006.08.030

acid mine drainage (AMD) (Benner et al., 2000). AMD is recognised as a multifactor pollutant. The main factors are acidity, salinisation, metal toxicity and sedimentation processes in natural water systems (Nordstrom and Alpers, 1999). The overall impact is largely controlled by the buffering capacity of receiving water and availability of dilution water (Gray, 1997). Inadequate control of AMD can result in substantial liabilities for both mine operators and regulators as a result of long-term environmental degradation (Needham and Books, 1997). Potential problems caused by AMD include:

- impact on mine water quality limiting reuse of mine water and process water and creating corrosion problems for mine infrastructure and equipment;
- impact on riparian flora and faunal communities (e.g. death of trees) along the downstream channels and around the source of AMD;
- impact on groundwater quality, particularly in shallow aquifers;
- impairment of the beneficial use of waterways downstream of mining operations for purposes such as stock watering, recreation, fishing or irrigation and
- difficulties in re-vegetating and stabilising mine wastes.

Nickel mining is often associated with acid mine drainage, since the nickel ore often occurs in sulphide form and associated with other sulphide minerals (Lupankwa et al., 2004). Nickel mines in Zimbabwe are mostly located in the upper catchments of transboundary river systems, as in the case of Trojan Nickel Mine in the Mazowe Valley (Ashton et al., 2001). Accordingly, managing the runoff quality of such operations is of strategic importance, considering also that there are urban, rural and commercial agricultural users of water in the area.

The objective of this study was to investigate the impact of the waste rock dump at Trojan Nickel Mine on surface water quality.

1.2. Site description

Mining of the sulphide bearing ore body at Trojan Nickel Mine which is located 90 km north of Harare (see Fig. 1), commenced in 1965, and the first nickel concentrates were produced in 1968. Mineralisation at Trojan Nickel Mine is hosted by serpentinised dunites interlayered with komatiitic and tholeiitic basalts, as well as sulphidic ironstones "cherts". There are also intrusive dolerite dykes. The main sulphide minerals in order of abundance are pyrrhotite ($Fe_{1-x}S$), pentlandite [$(Fe,Ni)_9S_8$] and chalcopyrite ($CuFeS_2$). Minor sulphides include pyrite (FeS), cobaltite [(Co,Fe)AsS], niccolite (NiAs), gersdorffite (NiAsS), and millerite (NiS) (Chimimba, 1987). Three ore types can be distinguished, the massive ore with 60–90% sulphides and a grade of 10% Ni, near massive ore with 30–40% sulphides and 4% Ni and disseminated ore with a cut off grade of 0.4% Ni and average grade of 0.6% Ni.

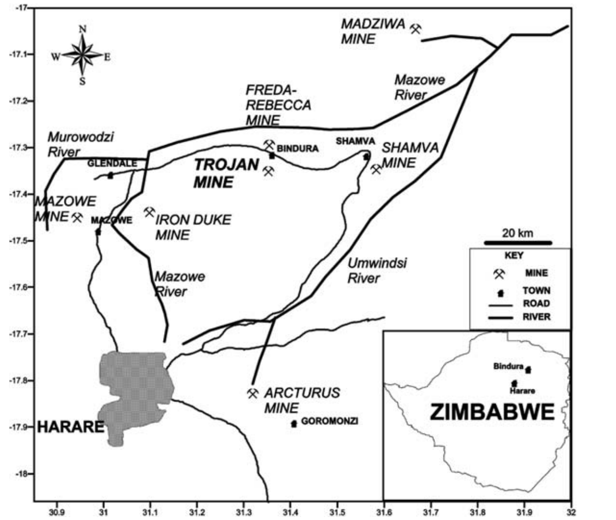

Fig. 1. Location of Trojan Nickel Mine in the Mazowe Valley, after Ravengai et al. (2004).

Dumping of the waste rock commenced in 1968. The method, called end dumping, that is used leads to grain-size sorting with finer material at the top and big boulders at the bottom (Mend, 1994). Between thirteen and fifteen tonnes of waste rock were being generated every month in 2000 from shaft sinking and primary development. There is one large waste rock dump and two small ones at Trojan nickel mine. The large dump is located in a valley just north of the concentrator. The rock waste has been piled on one large dump since then to the present day, with no lining at the base. The dump has four 'fingers' or blocks that are separated by empty spaces in between.

Runoff from the dump flows into a pond, constructed just southeast of the waste dump. The purpose of the pond is to collect, by settling, fine material from effluent that flows from the dump in order to avoid siltation of rivers downstream of the mine. The pond also collects water from the mine plant, specifically from the tailings thickener overflow and the concentrator. Much of the water in the pond is recycled, but some of it seeps through the wall of the pond and flows to the Pote River, a tributary of the transboundary Mazowe River. The stream that flows from the waste rock dump is referred to as the Waste Rock Stream in this study.

West of this stream is another stream that carries effluent pumped from the underground mine. This also flows into the Pote River and is referred to as the Underground Stream in this study. The Pote River, which is to the south of the mine, receives the effluent from the mine and drains into the Mazowe River.

2. Materials and methods

2.1. Surface water

Samples were collected in May 2002 from 11 sampling points at the pond, along the waste rock and underground