Influences on Mine Water Quality that are not Related to Acid Mine Drainage

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Abstract

Acid or neutral mine drainage (AMD/NMD) has the potential to cause problems with both ground and surface water. There are international and national guidelines to manage the potential influence of AMD and metal leachability from mine wastes and workings. Many techniques exist to predict and prevent AMD to reduce environmental impacts and avoid long-term mitigation expenses. What is less known and therefore less proactively managed are the influences on mine water quality by sources other than AMD. These could be from:

- Chemicals used during mining, processing and/or beneficiation,
- Sewage treatment plants,
- Explosive usage,
- Water treatment chemicals. and
- Hydrocarbons such as Polychlorinated Biphenyls (PCBs).

Substantial influences on water resources have been observed due to poor management of process chemicals and other inputs, even at mines where the waste rock is inert, with no AMD potential. Another common issue is nitrate contamination due to improper storage and poor management of nitrate-based explosives and incorrect sewage management.

The presentation will give results of a study at a platinum mine in South Africa. The host rocks are devoid of pyrite and no AMD potential or metal leachability exists. The aquifer is, however, contaminated with chloride that has migrated more than 17 km at concentrations well above the recommended limits. Thereafter, the plume is intercepted by a major river affecting the surface water and riverine ecosystem. The chloride concentration in the surface and groundwater is up to 1200 mg/L, while the background in the natural waters is less than 50 mg/L. Geochemical tests show that the chloride does not leach from the waste rocks, and the source is suspected to be from mineral processing chemicals.

A second example will be given of a mine in Tanzania where nitrate levels kept increasing due to long-term containment of sewage water and mine water, both containing nitrate. Contracts with explosive service providers had to be rewritten to ensure that the explosive is used to break rock and not end up in the water circuit.

This research has shown that while mines do invest and conduct proper investigations on the potential threat of mine drainage, influences from process chemicals are sometimes neglected, which could have adverse effects even after mine closure. A holistic environmental impact investigation would be required by considering not only the geochemistry of the waste rocks, but also the management of process chemicals.

Keywords: Groundwater quality, surface water quality, AMD, process water

Introduction

The discharge of AMD is well known as a major threat to aquatic ecosystems, soil quality, and overall environmental health. To address these concerns, legislation, regulations, and best practices have been enacted globally. Although the specific regulations my vary by country and region, they are all intended to characterise, predict, and manage AMD and metal leachability.

For example, in South Africa, where mining is a major economic activity, the National Environmental Management: Waste Act (NEMWA Act No. 59 of 2008 as amended by Act No. 26 of 2014) provides a framework for waste classification and leachability assessment. Based on the leachate severity, impermeable liners such as geomembranes or clay liners will be implemented to create a barrier beneath the waste rocks or a tailings storage facility (TSF).

While mines do invest and conduct proper investigations on the potential threat of AMD and associated metal dissolution, what is less known and therefore less proactively managed are the influence on mine water quality by sources other than AMD. These could be from:

- Chemicals used during mining, processing and/or beneficiation,
- Sewage treatment plants,
- Explosive usage,
- Water treatment chemicals,
- Input water from a contaminated source,
- Seepage from waste sites; and
- Hydrocarbons such as PCBs.

In this paper, two case studies are presented whereby anthropogenic sources have caused serious water quality deterioration at mines in South Africa and Tanzania. Intensive investigations and mitigation plans were implemented to prevent contamination due to the natural geochemistry of the waste rocks. However, waste generated from other processes ended up contaminating the water resources to unacceptable levels.

Chloride Contamination from Process Chemicals – A Case Study

Currently, most of the world's supply of platinum and associated elements is obtained from mines within four major igneous intrusions (Schouwstra et al. 2000). One of these is the Bushveld Complex of South Africa, which is the world's largest layered intrusion. Contamination of water resources (streams and aquifers) exists at one of these platinum mines where underground mining has been conducted since the 1960's.

The waste rocks are ultramafic dominated by norite, anorthosite, pyroxenite, and thin chromitite layers (Environmental Solution CC et al. 2002). The mineralogy largely consists of silicates, namely plagioclase $(Na,Ca)(Si,Al)_4O_8$, enstatite $(MgSiO_3)$, chromite $(FeCr_2O_4)$, quartz (SiO_2), hornblende $(Ca_2(Fe,Mg)_4Al(Si_7Al)O_{22}(OH,F)_2$, and smectite $(CaMg_2AlSi_4(OH)_2{\cdot}H_2O)$.

Geochemical assessments (Digby Wells 2023) and a track-record of groundwater monitoring showed that pyrite is absent from the host rocks and no AMD potential or metal leachability exist. Additionally, no chloride-bearing minerals were detected.

The background chloride concentration upgradient of the mine is approximately 50 mg/L. Hence, any chloride increase as the groundwater flows past the mine has been attributed to mining and processing activities.

The contaminated aquifer covers an area of approximately 50 km^2 (Fig. 1), and extends over a length of 17 km. The chloride concentration is up to 1200 mg/L, greatly surpassing the mine's discharge limit of 100 mg/L. The plume joins a major river to the northwest, affecting the surface water and riverine ecosystem. By the time the groundwater joins the river, the concentration is approximately 550 mg/L.

Currently the chloride source is not fully understood, and an investigation is underway. Since the chloride is not sourced from the waste rocks or tailings materials, it was suspected to be either from one or more of the process chemicals which are added for the flotation or from a water source. The recirculation of the mine water from the unlined TSFs and return water dams to the underground workings over the years has also resulted in higher salt concentrations with each circulation, as more and more chloride is added without a suitable outlet or removal system.

Excess mine water, although poor in quality, was used for years for irrigation north of the TSFs (Fig. 1). This area is in a different sub-catchment from where the TSFs and underground workings are. Mine water was also used for underground drilling and haul road dust suppression. The water eventually seeped into the subsurface and contaminated the aquifer.

A numerical model was developed to predict the fate and transport of the contamination plume. Considering the low recharge, current plume size, aquifer porosity, and rock permeability, the plume will only slightly improve under natural conditions even 100 years after mine closure.

The influence on water quality could have been avoided if the management of process chemicals, in addition to AMD characterisation, was postulated in advance of mine development. Contamination prevention is less costly and time effective than aquifer remediation. Nevertheless, the following could be undertaken to reduce the plume size and minimise environmental impacts on the riverine ecosystem:

- An investigation is underway for source-term chloride characterisation. Further addition of the chloride needs to be stopped by changing technologyI.
- The underground working is approximately 250 m beneath the TSFs, which are unlined. The mine abstracts a total of 11,600 m^3/d from the underground operation. Nearly 23% of this is contaminated mine water that is recycled back underground due to seepage from the storage facilities. The remaining 77% is clean fissure water that is flowing from the aquifer system. Clean groundwater should be intercepted from upgradient boreholes before it enters the operations. Since the background water is clean, the excess can be discharged safely without degrading the environment, which would allow the contaminated water to be contained.
- Although it is not practical to line the TSFs, it is possible to revegetate, cap, and cover them with less permeable clayey soil to minimise infiltration.

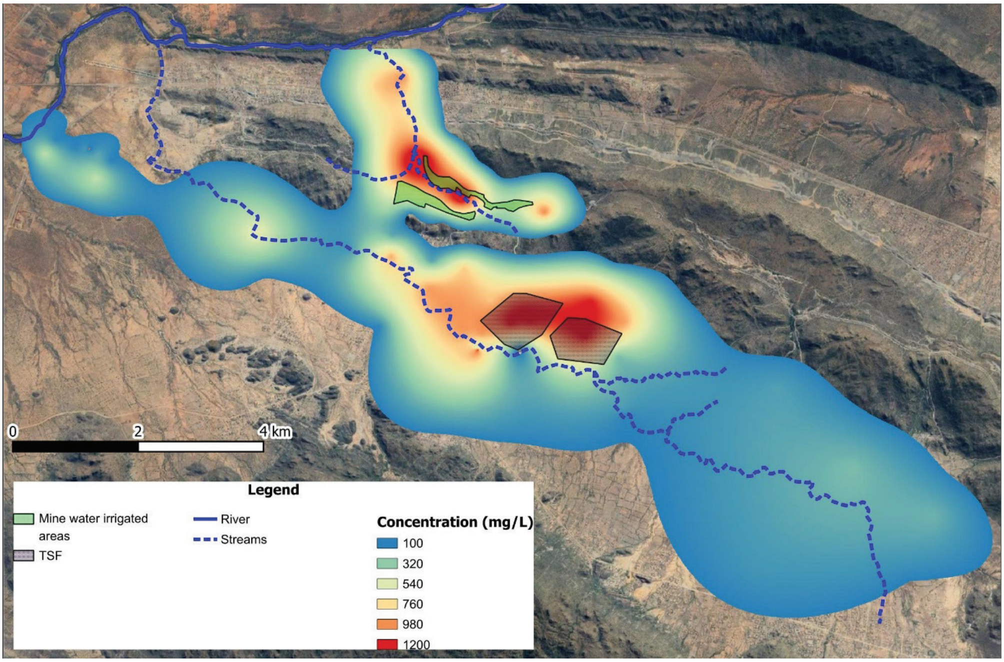

***Figure 1** Current Chloride Contamination Plume in the Aquifer*

- The return water ponds near the TSFs must be lined to reduce seepage into the underground workings, hence reducing aquifer contamination and dewatering costs.
- Excess mine water should not be used for irrigation, unless it is treated to acceptable levels.
- Even if the contamination source is contained, the current plume will stay behind long after mine closure. Active treatment such as pumping out of the contaminated water, followed by treatment is an option to be considered in order to speed up the recovery period.
- The mine is not acid-generating, and the geochemistry is not expected to change after closure. However, post-closure plans should also evaluate the potential influences of other waste products that are not related with rock mineralogy.

Nitrate Increase from Sewage and Mine Water – A Case Study

A mine in Tanzania with a positive water balance, i.e. more water is captured by rainfall and groundwater ingression than can be locked up in the system or evaporated, did not discharge water for a long period of time and kept water in ponds and behind their tailings dam. This included sewage, process, and mine waters. The water volumes built up to dangerous levels and there was a very large load of chloride and nitrate contained in these waters. In order to discharge the water, treatment was necessary to meet discharge standards and thus large reverse osmosis (RO) plants were installed. For a while, the brine was circulated back into the systems and thus the bivalent ions built up to saturation levels and chloride and nitrate continued to build up without limit. The TSF is not acid-generating and there are no trace metals leaching from the waste rock. Salt loads in the TSF pool originated from the sewage and process waters. Detailed water and salt balances were compiled showing chloride to be the limiting element.

Changes instituted into the water management framework were:

- Changing attitudes by getting personnel to buy into the idea that water discharge had to happen and should be done in a controlled manner and that pollution control dams (PCDs) should normally be kept empty,
- Reducing water ingression by reducing water capture,
- Sewage water stopped being added to the TSF and was discharged to a passive treatment system utilising eucalyptus trees and wetlands.
- The sewage treatment plant was improved,
- Explosive manufacturers and blasting systems were changed to optimise rock fragmentation and minimise nitrate wastage into the water systems,
- Discharge of water was encouraged, and chloride and nitrate levels were maximised in the discharge waters but kept below discharge limits, and
- Biological sampling was instituted to monitor the influence of the discharges, and chemical sampling was systematised for the same reasons.

It was necessary to install a high-water recovery technology plant that combined RO with sulfate and calcium precipitation steps in order to treat the highly saline waters. The nitrate, not the chloride, turned out to be the limiting elements in the waters and the highly saline brine is now stored in double lined ponds for evaporation, further treatment, and blending to reduce volumes. The mine now operates in a controlled and safe manner with respect to water storage, provision, and discharge.

Conclusions

Mining operations generate a variety of waste materials and by-products through their numerous and diverse activities. While AMD is a well-documented concern, this paper has shown that it is crucial to recognize and address the diverse contaminant sources beyond this specific issue. Comprehensive environmental impact assessments are essential to mitigate the various factors influencing mine water quality and ensure the long-term health of surrounding ecosystems.

All contamination sources must be understood irrespective of whether they are inherently associated with the waste rock chemistry or anthropogenic. This is essential if any remediation is to be implemented, since water treatment will not produce the intended result if the source is not appropriately characterised.

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