OPINION

Mine drainage and rehabilitation: some comments

Handré Brand provides an overview of the environmental challenges experienced by mining in South Africa.

"Our forebears deferred the environmental costs associated with mining, and we now have to pay those costs. Are we going to do the same to future generations? If we do, their problems are likely to be far more severe than ours because the effects are cumulative and in the future, once mining is on the wane, the funds to address the problem might not be readily available." (McCarthy 2011:1)

Water with increased acid content as well as acid-neutral metal-rich water from obsolete metal mines is often a source of pollution for rivers (Nordstrom 2011). The former contain metals such as iron, copper, and aluminum, while the latter may contain arsenic, antimony, and uranium, among others.

The contamination of both surface and groundwater can result from poor or faulty water drainage systems (adits) in well-mapped mines. In many cases, however, it also stems from mines that have long been closed and for which there is little if any historical data.

In the UK, Todd and colleagues (2024) from the Department of Geography at the University of Swansea, undertook a long-term study of the changes in water quality of three Welsh metal mines. All three mines – Nantymwyn, Paris Mountain and Frongoch – have been abandoned and/or closed since the early twentieth century.

Using available data from blind samples (spot/grab sampling)-(Dixon u.d.) provided by environmental regulators, the researchers found that metals were constantly leaching or seeping to riverbeds, and that the metal concentrations of the mine water decreased little if at all. This figure out occurs at mines where no mine-water remediation has been applied, and continues despite time lapse and/or weathering.

At the Nantymwyn mine, comparisons between five monthly samples in 2019 showed no significant changes ($p > 0.05$) in metal concentrations compared to the same period in 1985. At Paris Mountain, there was a 2% increase in filtered zinc concentrations from 2004 to 2020. The environmental impact at Frongoch, in turn, diminished significantly after mine-water remediation commenced: For example, the total lead concentration dropped by 90%.

Water pollution from metal mines therefore does not necessarily spontaneously decrease in the decades following their closure. This observation should be a wake-up call for industry and relevant government departments to give priority attention to mine assessment and rehabilitation.

Similar international examples at the sites of mine management, mine drainage, groundwater contamination, and mine water rehabilitation are the Cadia gold mine in Orange, Australia (Hambrett 2024), Berkeley Pit, United States (PitWatch 2024), and the Ranger uranium mine in Australia (Johnston and Needham 2002). Hattingh (2024) mentions that in South Africa the surrounding water supplies and land were negatively impacted for decades or even centuries by the active discharge, seepage, run-off, and dust emissions from abandoned or inadequately repaired mines.

Local state of affairs

South Africa's mineral wealth developed over a geological period of approximately 3.7 billion years (Wassenaar 2011). A total of 80% of the world's manganese reserves, 73% of the chromium reserves, 88% of the platinum reserves and 45% of gold reserves are found here. The national economy is therefore closely intertwined with the exploitation of mineral resources. However, the groundwater level and unweathered rock bottom were not penetrated through mining activities until the 1860s. Mineral ore in its original form is non-renewable, and thus many of the current mining practices in mining are putting the industry's reputation at serious risk.

According to Wassenaar (2011), a researcher at the Unit for Conservation Ecology of the University of Pretoria, the chemical and radiological pollution of water at the coal mines on the Highveld is a good example of the interactive nature of mining and natural systems and consequently points to the complexity of environmental management in a modern mine. Pyrite comes into contact with oxygen-rich water, which gives rise to acidified surface and groundwater, and has catastrophic consequences for the ecology further downstream. Large parts of the Olifants River and dams at Witbank and Middelburg are affected. Many of the mines have long been closed, limiting the possibility of rehabilitation.

McCarthy (2011) from the School of Geosciences at the University of the Witwatersrand points out that the fragmentation of rock masses during mining and mineral extraction dramatically increases the surface area and thus the rate of acid production. Certain host rocks, especially those containing large amounts of calcite or dolomite, possess the ability to neutralise the acid. However, this is not the case for coal

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and gold deposits: Here the natural neutralisation processes are overwhelmed, and mining operations release large quantities of acid water into the environment – initially into groundwater, and eventually into streams and rivers. The acidic water increases the solubility of any aluminium and heavy metals that may be present in the affected area. The overall result is that the water is polluted to varying degrees. Finally, the water is neutralised by a combination of dilution and reaction with river sediment or various soil minerals. Nevertheless, certain ingredients (including sulfates) are extremely soluble and continue to exist in the water.

Not all of South Africa's mineral deposits are associated with acid production: Diamond, iron, manganese, chromium and vanadium mines, for example, do not create acid wastes, and most platinum mines apparently do not have this problem either.

Surprisingly, in certain circumstances, polluted mine water can be used to irrigate crops. Scientific tests show that in the short term, water with high concentrations of calcium or magnesium sulfate has minimal effects on crop health and the environment (Wassenaar 2011). Annandale and colleagues (2002) investigated the sustainability of crop irrigation with gypsum-containing mine water. Gypsum is a soluble source of calcium and sulphur (in sulphate form) which can be used as a plant nutrient source. In the researchers' multidisciplinary study, different irrigation methods were used, and crop response to the gypsum water as well as its impact on soil and groundwater were examined. Field trials were conducted at two mines – Landau and Kleinkopje coal mines in Mpumalanga. A wide variety of crops were irrigated with gypsum water, and could be successfully harvested for commercial purposes. Chemical analyses of water quality in the soil placed under irrigation showed no significant soil water contamination over a three-year period.

Cole, Chimbganda, Esau, Abrams and Broadhurst (2024) developed a mine closure framework for South Africa. The main goal of this project was to create national maps and classifications of local mine closure risks and opportunities. This information is intended to guide and support mine closure planning and policy in the country (for more information, see the May/June 2024 edition of the Water Wheel)..

Policy matters

The overall objective of the Department of Water and Sanitation's (DWS') Mine Water Management Policy (DWS, 2022:4) is to provide guidelines for a coherently integrated approach to mine-water management by government, the private sector and civil society. This occurs by building on existing legislation, addressing glaring gaps, constraints and shortcomings, and by utilising existing mine and acid water management solutions and strategies as best as possible.

The Mine Water Management Policy is guided by, and is based on, existing initiatives to support mine water management, such as the full implementation of the National Water Amendment Act 27 of 2014 and the National Environmental Management Laws Amendment Act 25 of 2014. Therefore, the comprehensive policy supports a number of principles enshrined in existing legislation.

These include cancelling the mining rights, permits or prospecting rights of mining companies that cause unacceptable pollution of water resources (DWS 2022:21), and an insistence on proper infrastructure transfer after mine closures to ensure sustainable management (DWS 2022:26–27). The policy states that the 'polluter pay' principle will be applied to mine-water in all forms in the context of national environmental management principles, and that this approach to retroactive accountability will be applied in conjunction with international norms and definitions to cater for multinational mining companies (DWS 2022:27–28). In addition, the policy aims to protect and empower poor and vulnerable communities throughout the entire mining value chain, which includes the mine water management cycle (DWS 2022:29).

Both the Water Institute of Southern Africa (Division of Mine Water) (WISA u.d.) and the Water Research Commission (Division of Water and Wastewater Management) (2018) encourage practical and academic collaboration between the community, state and private sector to promote proactive mine water management and rehabilitation (Van der Merwe 2024). The South African Chamber of Mines (2007) emphasises that the quality of surface and ground water flowing from mining sites must continuously – in other words during production, after mine closure and in the future thereafter – meet the following criteria:

- Surface water drainage systems and surface water quality

The operation of surface water drainage systems should be monitored annually, preferably after the first major rains of the season, and again after any major storms. This will ensure that mine drainage goes according to plan and that drainage structures that are not working properly are repaired well in advance before they break and cause significant erosion damage. The quality of the water leaving the premises (as well as water anywhere else on the premises, as specified by the DWS) must be monitored regularly. Water samples should be analyzed for particle and soluble contaminants and biological contamination (SA Chamber of Mines 2007:51).

Mines can pollute the environment decades after closure if appropriate rehabilitation measures are not taken.

- Groundwater quality

The quality of groundwater should also be measured at certain designated locations. A hydrogeologist should determine the location of the monitoring points in conjunction with the regulatory authority. Monitoring points should be located (hydrologically) downhill from the rehabilitated area. The regulator determines the regularity of monitoring, although monthly monitoring is usually required in the first year or two after the installation of the monitoring wells. After that, monitoring can be reduced to once a quarter or, in extraordinary circumstances, even once a year, provided that monitoring results over time indicate little or no change (SA Chamber of Mines 2007:51).

Some research studies

In 2018, the Centre for Environmental Rights analysed eleven listed mining companies' feedback on their financial provision for environmental rehabilitation (in other words, their budget allocation for the redress of environmental damage arising from their operations).

The purpose of corporate disclosure legislation and accounting standards is, among other things, to ensure transparency and accountability in companies' financial provision for environmental rehabilitation. These include budgets for and the cost of environmental rehabilitation. Nevertheless, the information provided by the mining companies involved in the Centre for Environmental Rights' survey was inconsistent, unclear and in some cases unreliable, and also not mutually comparable (Centre for Environmental Rights 2018:2). Thus, it seems an impossible task for shareholders or taxpayers to hold companies or regulators to account.

Regarding this, Almano (2022) from the University of Cape Town says the following:

"So, while legislation places a duty on companies to ensure they prevent damage to the environment where possible, it is not difficult to see that policy and legislation have failed to provide a regulatory framework which adequately and effectively scaffolds the closure and rehabilitation of mines in South Africa. Rehabilitation rarely seems to occur. This is evidenced by a reported 6000 abandoned mines across South Africa. These issues are furthered by the Department of Mineral Resources ("DMR") and its poor compliance, enforcement, and monitoring of mining rehabilitation".

In the same vein, Tempelhoff highlights the profound environmental implications of the occurrence of acid mine water at Tweelopiespruit on the West Rand. According to Du Rand (2016), affiliated with the Department of Zoology at the University of Johannesburg, macroinvertebrate aquatic mammal species are largely absent in the Tweelopie and Rietspruit, whose pH has ranged from 2,4 to 4,6 since 2011.

Surface and groundwater pollution from mines is a thorny issue in South Africa. In particular, the gold mines on the West and East Rand and the coal mines in Mpumalanga are significant polluters. Other sources are the vanadium mines, which release extremely toxic vanadium pentoxide into soil and surface water. For example, Lötter (2024) points out that significant numbers of deaths among large bird species such as Egyptian geese (*Alopochen aegyptiaca*) were found at a dam on the Steelpoort vanadium mine. The source of pollution was tracked using geophysics procedures to a burst pipe near the metallurgical plant on the mine.

A research group affiliated with the Central University of Technology (Belle e.a. 2021) argues that the gold mining tailings of mines in the Welkom and Virginia area of the Free State contain several contaminants. The extent of groundwater contamination in the area was studied by measuring several water quality indicators at eight sampling points that fall into three different zones. The overall groundwater contamination was quantified against a drinking water quality index. The finding was that most groundwater in the Welkom and Virginia area is unsuitable for drinking purposes. At only three test sites, the water samples were suitable for human consumption. Water quality was poor at 40% of test sites, and particularly poor at one site.

These results were substantiated by the high scores for all microbiological indicators. Fecal coliform bacteria counts exceeded both the limits of the World Health Organisation and the South African National Drinking Water Standards. At 50% of the measurement points, E. coli scores were also higher than the prescribed limit for drinking water. In terms of the appearance of harmful elements, lead and iron were present in toxic concentrations. Since groundwater is the main source of drinking water for the local residents of the Welkom and Virginia area, their health is therefore in serious danger.

Conclusions

International research on pollution from abandoned metal mines indicates an ongoing deterioration in water quality even decades after the closure of the mines. This highlights the urgent need for continuous mine assessment and innovative rehabilitation techniques. The information consulted highlighted the seriousness of water pollution from mines in South Africa, especially in regions with extensive mining activities such as the West and East Rand and Mpumalanga.

There are significant gaps to be found in the regulatory framework and its practical application. This is testimony to the occurrence of polluted soil and surface water around numerous abandoned mines, as well as discrepancies in mining companies' financial provision for environmental rehabilitation. Continued research is essential to form a better understanding of the complex interaction between mine drainage and the environment, and to develop new and innovative mitigation strategies. Regular scope surveys by independent institutions such as the Water Institute of Southern Africa and the Water Research Commission should be considered.

This contribution is by no means presented as a complete overview of the complex research site of mine drainage and rehabilitation. However, the hope is that it will help give renewed focus to South Africa's approach to this complex and significant environmental problem.

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