The status and implications of the AMD legacy facing South Africa

Mosidi Makgae

Council for Geoscience, Environmental Geoscience Unit, 280 Pretoria road, Silverton, 0001, mmakgae@geoscience.org.za

Abstract

Following the discovery of gold in South Africa in 1886, the mining industry played a central role in the country's economic, political and social environment. The early mining economy was simply an extractive industry with little consideration given to possibly adverse long term effects. It is only recently that South Africa incorporated the objectives of sustainability and social justice to its constitution. Despite significant progress being made in South Africa in shifting policy frameworks to address mine closure and mine water management, and the mining industry changing practices to conform to new legislation and regulations, the current situation still poses threats.

In South Africa for example, the Witwatersrand Gold fields in particular the East Rand, West Rand and Central Rand, are a source of AMD which poses socio-economic and environmental threat. When mining for gold, miners had to pump out all the inflowing water, which continually fills again. Currently the problem is that the untreated AMD is filling the underground mine workings and now AMD instead of fresh spring water, is threatening to rise to ground level.

It is evident that there is a need for a better understanding of the methods that can be used to control or limit AMD pollution from occurring. Currently, the South African government is investing money in trying to address these AMD-posed challenges through various government departments.

Keywords: AMD, abandoned mines, water resources, environment

Introduction

This paper seeks to highlight the challenges that South Africa is facing today in terms of AMD from the abandoned and ownerless coal and gold mines and the government's attempt to address these challenges. These ownerless mines are now the State's liabilities because of their impact into the environment and the public, and the cost of addressing these challenges is huge.

South Africa has a long history of mining and has only recently developed and implemented comprehensive legislation to regulate environmental management and mine closure processes. Unfortunately, a large number of historical mining operations have been abandoned by their operators with little or no regard for their impacts on public health and safety, and the environment. This situation has led to the existence of a large number of derelict and ownerless mines which, in terms of South African legislation, become the responsibility of the state (Swart 2003). Acidic drainage is found around the world both as a result of naturally occurring processes and activities associated with land disturbances, such as mining where acid-forming minerals are exposed at the surface of the earth (Akcil and Koldas 2006). These acidic conditions can cause metals in geologic materials to dissolve, which can lead to impairment of water quality when used by terrestrial or aquatic organisms.

Gold Mining

In South Africa, particularly in the Witwatersrand gold fields in Gauteng Province (see Figure 1), as gold was mined from greater depth, an un-oxidised pyritic ore was encountered, and the process became inefficient. The cyanide extraction then started around 1915 because it was highly selective for Au and Ag but it required finer milling. The resultant tailings were piped to disposal sites, known as slimes dumps. These mine dumps today are major contributors of acid mine drainage formation and heavy metals pollution. Typical heavy metals that have been detected and analysed from these dumps are As, Co, Cu, Ni, Pb, U and Zn (Tutu 2008). These conditions have adversely affected the surface and ground water quality, in a country where water is a scarce resource.

The challenge that South Africa is now facing is that many of these gold mines are ownerless and abandoned or had become insolvent before the full environmental and socio-economic impacts caused by them became evident and, thus, cannot be legally compelled to remediate these negative impacts (Naicker et al. 2003).

Coal Mining

Coal is widely mined in South Africa as an energy resource and source of income from exports. It is today, and will still be in the future the most important global source of electricity (World Coal Institute 2002). Its environmental impact has been a challenge. These coal mines have caused land subsidence, pollution of water environments, disposal of mine waste and air pollution.

Most of the derelict and ownerless coal mines are found in the Mpumalanga Province. According to Bell et al. (2001) the coal mining operations around the 1908 used the room and pillar method, and later around the 1930s to the 1940s the pillars were robbed over extensive mining area. This resulted in subsidence formation, which led to the surface fracturing. The resultant formation of acid mine drainage and mine subsidence have an immediate effect on the water environment due to the connection of underground water bodies to the mined space through fractured overburden (Bian et al. 2010).

Causes of Acid mine drainage

AMD generally emanates from mine waste rock, tailings, and mine structures, such as pits and underground workings, and is primarily a function of the mineralogy of local rock material and the availability of water and oxygen (Valente and Gomez 2009). According to Akcil and Koldas (2006) it is estimated that mining and ore processing have resulted in mine tailings that are currently exposed to weathering. Most of these Wits basin sites pose a serious environmental challenge for clean-up and on-site remediation, because of their impact on the water resources, both surface and ground waters.

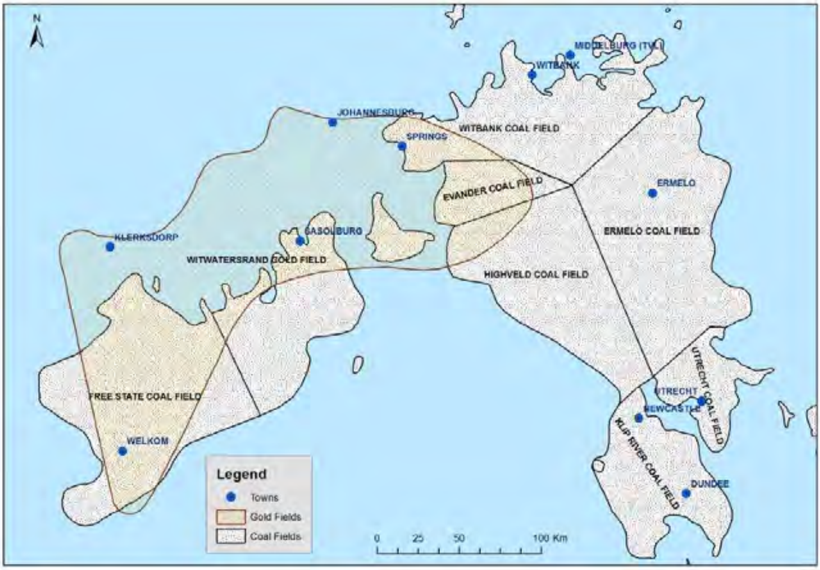

Figure1 *Map of major coal and gold fields in South Africa*

In South Africa these acid streams occur mainly as a result of mining activities from certain types of mineral deposits such as coal mainly from Witbank and Ermelo coal fields and gold from the Witwatersrand gold fields, see Figure 1 *(*Durand 2012). Water contaminated by AMD often contains elevated concentrations of metals, which can be toxic to aquatic organisms, leaving receiving streams devoid of most living creatures. The receiving waters may have pH as low as 2.0 to 4.5, levels toxic to many forms of aquatic life. The corrosive nature of these acidic waters and presence of high trace element concentrations in sediments and aqueous phases (concentrations can be 1000 times higher than un-impacted areas) in AMD affected sites raise serious environmental issues. Remediation of these AMD contaminated sites is not only expensive but is a tedious process.

Every mine is unique in terms of its AMD potential; thus, the nature and size of the associated risk and feasibility of mitigation options will vary from one site-to another. This is despite the fact that the International Network of Acid Prevention created a Global Acid Rock Drainage Guide which is aimed to provide world-wide reference for acid prevention and to identify Best Practice in the field of ARD (Bezuidenhout et al. 2009).

Societal Impacts

Some communities living in the rural areas adjacent to the mines in western Gauteng, Mpumalanga and North West Province are dependent on groundwater from boreholes due to the lack of municipal water (Durand 2012). The farming communities and people living in informal settlements use groundwater and surface water for drinking purposes, to water livestock, and to irrigate crops. In cases where the water used for irrigation is contaminated by mine effluent, the potential exists for metal bioaccumulation in crops and consequently, this would pose a human health risk (Van Eeden 2006; Davies and Mundalamo 2010).

Environmental Impacts

Environmental studies, which include water and sediment analyses, and radioactivity and biodiversity surveys, have been done in South Africa over the past few years. AMD leads to the decimation of aquatic life in the water bodies into which mine effluent is discharged. The acidity, salinity, turbidity, toxicity and radioactive value of the receiving water bodies are affected (Durand 2012). Metals and other pollutants are accumulated in organisms as they pass through the food chain. During the process of bioaccumulation, some toxins can become more concentrated as they travel up the food chain and have a detrimental effect on higher trophic levels (Luis et al. 2008).

Economic Impacts

The cost of mitigation of environmental damage from acid mine drainage is huge. Acidic mine drainage has been identified as the largest environmental liability facing the South African government (Oelofse 2012). AMD has increased treatment costs because increased loads of discharged effluents will increase the costs associated with purifying water for domestic consumption and agricultural use. According to Johnson and Hallberg (2005) treatment technologies to address the AMD problems are very costly. The South African government is currently investing a lot of money in research in pursuit of environmental solution.

Legal Implications

The efflux of AMD-contaminated water is the most costly environmental and socio-economic problem in South Africa (Oelofse 2010). Attempts by government departments to involve the mining companies in the rehabilitation of the areas impacted by mining activities have been frustrated because of the mine companies' refusal to accept responsibility for the situation (Van Eeden et al. 2009). Mine companies usually claim that they inherited the situation which already existed before they took over the mine properties. Most gold mines, particularly on the Central Rand, East Rand and West Rand were abandoned or liquidated before the environmental and health impacts became evident.

Mine closure in terms of the Minerals and Petroleum Resources Development Act (MPRDA), 2002

South Africa has a rich history of over a century of mining, which has been a vital component of the development of the country. At the same time, mining has resulted in major impacts, both environmental and social. Many of these impacts have not been fully recognised or dealt with properly in the past. South Africa now has a legal framework that instructs the mining industry on what to do to minimize environmental and socio-economic impacts with guidelines on how to achieve compliance with the laws concerned with mining activities. However, for a long part of the mining history legislation endorsing appropriate rehabilitation and recovery of mine-impacted land and natural resources was lacking.

South Africa now has both the National Environmental Management Act (NEMA) (Act 107 of 1998) and the National Water Act (Act 36 of 1998) stipulating that a party has to take all reasonable measures to prevent pollution or degradation from occurring, continuing, or recurring as a result of mining operations for which it is responsible. According to these Acts, investigations, training, ceasing or modification of activities or processes, containment, and remediation have to be undertaken by the responsible party. The Mineral and Petroleum Resources Development Act (Act No. 28 of 2002) stipulates in section 38(1)(d) that the holder of the mining permit must take responsibility for the rehabilitation of the environment affected by mining to its natural state or to comply with the principle of sustainable development as far is reasonably practicable.

The MPRDA (2002) is certainly a milestone in the transformation of the mining industry in all aspects. This Act provides a holistic cradle-to-grave approach to prospecting and mining by fully considering economic, social and environmental costs to achieve sustainable development of SA mineral resources. According to Usher (2009), Section 37 of the MPRDA (2002) confirms the adoption of the principles for sustainable development as set out in section 2 of NEMA (1998) as well as other generally accepted principles of sustainable development, by integrating social, economic and environmental factors into the planning, implementation, closure and post-closure management of prospecting and mining operations (Swart 2003).

Treatment options for Acid Mine Drainage

The primary management issues for underground gold mine closure include long term decant risk, acid mine drainage, water pumping and treatment and allocation of responsibility especially in light of the interconnectedness of the mines.

The requirement of water treatment for elevated metal levels and acidity is a common outcome of acid mine drainage. The effectiveness and feasibility of water treatment is highly variable depending on the treatments employed and unique site characteristics. According to Johnson and Hallberg (2005), water treatment installations may include both passive and active systems. Passive water treatment systems, typically wetlands, operate without chemical amendments and without motorized or mechanized assistance. In contrast active water treatment systems are highly engineered water treatment facilities commonly employing chemical amendment of acid mine water to achieve a water quality standard specified in a discharge permit.

In South Africa, there are several AMD ‘hot spots’ which require urgent intervention to prevent total ecological disaster. These hot spots have largely driven research into new technologies for the management and treatment of polluted mine-water. Extensive degradation of surface waters by the effluents from abandoned mines and mine wastes has made treatment of effluents imperative in the mining communities.

Council for Geoscience (CGS) has been involved in some research for Department of Mineral Resources (DMR) over the past few years. The AMD hotspots were found around the Witwatersrand gold fields' area and Witbank and Ermelo coal fields' area. In both these major coal and gold fields, the water quality has been found to be around pH 3-4, with EC of about 5000 mS/cm. The results show high levels of SO_4^{2-}, Cl^-, Fe, Al, Ni, Cu, Cr, Mn, Co Pb and U. They simply imply that urgent intervention and strategy to minimise AMD impacts on the environment is required.

This year the DMR has awarded a contract to CGS for the management of derelict and ownerless mines as part of the government's contingent liability. There are various remedial strategies developed for implementation at mine sites, and here are some of the examples of such; the collection and treatment of contaminated surface and ground waters, passive treatment of contaminated surface water using constructed wetlands, treatment of contaminated ground water using permeable reactive barriers or other in situ remedial approaches; the placement of covers on tailings impoundments and waste rock piles to prevent oxygen ingress, Johnson and Hallberg (2005).

The CGS approach agrees to Van Eeden et al. (2009) that it is critical that water-related remediation studies should include a consideration of environmental ethics, environmental responsibilities, liability, and equity. This approach could change the situation of conflict to cooperative efforts between the many mining companies, especially coal and gold, conservationists, activists, and inhabitants in those affected areas.

Discussions and Conclusion

AMD is a significant and costly environmental challenge facing in particular the South African government because most of these are abandoned and ownerless mines. Characterized by low pH and high concentrations of heavy metals and other toxic elements, AMD can severely contaminate surface and groundwater, as well as soils.

It is therefore interesting to look at the argument raised by Mudd (2007) that there are two primary approaches to addressing AMD; Firstly to circumvent mining sulphide rich ore deposits with high AMD potential and secondly, implementing mitigation measures to limit potential AMD impacts. It is noted that avoiding mining of sulphide ores with the potential to form AMD may be difficult because they are most often associated with the mineral resources of interest. This is true for South Africa because our economy is primarily dependent on mining. It becomes therefore imperative to apply mitigation measures to limit potential AMD impacts.

Unfortunately mines have a limited lifespan and the closer they come to mine closure, the less money they have due to a reduction of the revenue generated. In some cases, virtually no money would be available either for the rehabilitation of the environment or for compensation to people with health claims against the mine company. This is because at the time the MPRD Act was not there to prescribe to the mining license applicants that the financial provision be made available for mine closure. The challenge in South Africa is that most of these mines that are contributing to this AMD challenges are abandoned and ownerless, and as such they become the government's liabilities.

The impact of historical mining waste can have lasting environmental and socio-economic consequences and be extremely difficult and costly to address through remedial measures.

The threat of AMD to the environment if not solved in the short to medium term is likely to persist for centuries to come. In that case AMD threatens the scarce water resources of South Africa and as a result, also human health and food security around the mining areas.

In response to the challenge presented by mitigation of AMD, many technology-based reports were generated to evaluate sampling, prediction, prevention, treatment and monitoring of potentially acid-generating materials and locations. Currently in addition to the management of derelict and ownerless mines project, the government is spending lot of money in the process of addressing the AMD challenges by implementing the recommendations from the Team of Experts' report (2010) to the Inter Ministerial Committee Report that:

- Water must be pumped and treated from the three priority Witwatersrand's basins to maintain water levels at least below the relevant Environmental Critical Levels or, by agreement with stakeholders, the lowest level of underground activity within the basin.
- Steps must be implemented to reduce the ingress of water into the underground workings as far as is possible. This will reduce the volumes of water which need to be pumped and treated to more acceptable levels and consequently reduce the operational costs of AMD management.

These approaches will only be employed as short to medium term solution, while effective long term solutions are still under investigation.

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References

Akcil A, Koldas, S (2006) Acid Mine Drainage (AMD): Causes, Treatment and Case studies, Journal of Cleaner Production 14: 1139-1145.

Bell FG, Bullock SET, Halbich TFJ, Lindsay P (2001) Environmental impacts associated with an abandoned mine in the Witbank Coalfields, South Africa. International Journal of coal geology 45:195-216.

Bezuidenhout N, Verburg R, Chatwin T, Ferguson K (2009) INAP's global acid rock drainage guide and the current state of Acid Rock Drainage assessment and management in South Africa, International Mine Water Conference Proceedings, 19-23rd October 2009, Pretoria, South Africa.

Bian Z, Inyang H, Daniel S J, Otto F, Struthers S (2010) Environmental issues from coal mining and their solutions, Mining Science and Technology 20(2): 215-223.

Davies TC, Mundalamo HR (2010) Environmental health impacts of dispersed mineralisation in South Africa, Journal of African Earth Sciences, 58: 652–666.

Durand JF (2012) The impact of gold mining in the Witwatersrand on the rivers and karst system of Gauteng and Northwest Province, South Africa, Journal of African Earth Sciences 68: 24–43.

Johnson DB, Hallberg KB (2005) Acid mine drainage remediation options: A Review. Science of the Total Environment 338: 3-14.

Luís AT, Teixeira P, Almeida SFP, Ector L, Matos JX, Ferreira da Silva EA (2008) Impact of Acid Mine Drainage (AMD) on Water Quality, Stream Sediments and Periphytic Diatom Communities in the Surrounding Streams of Aljustrel Mining Area, Water Air Soil Pollut, p1-21.

Mudd G M (2007) Global trends in gold mining: Towards quantifying environmental and resource sustainability? Resources Policy 32: 42–56.

Naicker K, Cukrowska E, McCarthy TS (2003) Acid mine drainage arising from gold mining activity in Johannesburg South Africa, Environmental pollution 122: 29-40.

Oelofse S (2010) The pollution reality of gold mining waste on the Witwatersrand, Waste water management, ReSource, 51-55.

Swart E (2003) The South African legislative framework for mine closure, The Journal of The South African Institute of Mining and Metallurgy, p 489-492.

Team of Experts Report (2010) Mine Water Management in the Witwatersrand goldfields with special emphasis on AMD, Report to the Inter Ministerial Committee on acid mine drainage, South Africa.

Tutu H, McCarthy TS, Cukrowska E (2008) The chemical characteristics of acid mine drainage with particular reference to sources, distribution and remediation: The Witwatersrand Basin, South Africa as a case study, Applied Geochemistry 23: 3666–3684.

Usher BH (2009) Upscaling laboratory results for water quality at underground collieries in South Africa, Minerals Engineering 22: 43–56.

Valente T M, Gomez CL (2009) Occurrence, properties and pollution potential of environmental minerals in acid mine drainage. The science of the total environment 407 (3): 1135-1152.

Van Eeden ES, Liefferink M, Durand JF (2009) Legal issues concerning mine closure and social responsibility on the West Rand, The Journal for Transdisciplinary Research in Southern Africa 5 (1): 51-71.

World Coal Institute (2002) Coal: Delivering sustainable development, Proceedings of the World Summit on Sustainable Development and Its Implications, New York: Energy/Ge.1: 1-8.