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Compiled by: Arthur Chapman
Series editor: Bärbel Haldenwang

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Acid mine drainage in South Africa: An emerging environmental problem

Executive Summary

Acid mine drainage (AMD) is emerging as one of the greatest environmental threats facing South Africa. Concentrated along the edge of the Wits basin gold fields, and in the disused coal workings of the Mpumulanga Highveld, tens of thousands of m^3 of highly acidic, metal and sulphate-enriched water is decanting into river systems from underground workings and tailings dumps. The highly toxic effluent destroys aquatic life and poses serious health threats to people dependent on surface or groundwater in the region. Public concerns have pressured a government response, which promises a treat and release option. The disposal of resulting contaminated sludges has not been mentioned. The timing of the development of the necessary treatment infrastructure remain a concern. Nevertheless, the legacy of a century of mining and dumping of waste material has committed South Africa to the costs of treatment of acidic and metal-enriched toxic effluent water for centuries.

Problem statement

Acid mine drainage (AMD) and acid rock drainage (ARD) are emerging as two of the most important threats to the environment in the catchments and groundwater systems of the gold mining and coal mining areas of South Africa. AMD is the outflow of acid water from metal and coal mines, acidified by contact with sulphide minerals in the host rock (Akcil & Koldas, 2006). In South African gold and coal mines, iron pyrites (FeS) are present as sulphide minerals. Mining processes expose these metaliferous sulphides to air and water, allowing oxidation of the metal component and releasing hydrogen ions that create acidity. Any mining operation exploiting a sulphide ore body will be prone to generate AMD, so these issues also include mining operations involving zinc, copper or nickel sulphide orebodies (Akcil & Koldas, 2006).

High acidity leaches heavy metals from surrounding rock and mine dump tailings – iron, manganese, lead, arsenic, cadmium, cobalt and uranium are the most common heavy metal constituents. While some metals in trace amounts are necessary to human and animal health (ie, iron, copper, manganese and zinc), heavy metals are acutely toxic. Aluminium is not a heavy metal by definition, but because of its relative abundance it causes concern and it is implicated in several health disorders. Poisoning by these metals results in damage to the mental and central nervous systems, damage to the composition of blood, and all vital organs. Metal accumulation in the body results in progressive muscular and neurological degenerative diseases. Even very low concentrations of heavy metals can have severe health effects; hence the need to understand their source, mode of bioavailability and pathways of ingestion.

Frequently in the news recently, outflows of water from abandoned or decommissioned gold mines in the Wits basin and from the toes of the large slimes dams or tailings dumps have a pH of 2-3 and are strongly acidic (Coetzee, 2005; Oelofse *et al*, 2008). The discoloured water, contaminated with sulphates and heavy metals, is discharging into surface waters close to where many people live and which people sometimes utilise, into wetlands of international importance and into the headwaters of major South African river catchments. Unseen, groundwater is also being contaminated by plumes flowing from the mine shafts (Hobbs & Cobbing, 2008). The physical evidence of the effect is the intense orange-red or yellow colours, caused by precipitation of iron oxides and oxyhydroxides, now seen for example in the Tweelopiespruit. It is also the reason for the name given to the Rio Tinto River in Spain (Ettema, 2005).

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Specific concerns have been raised about the high levels of uranium in the polluted effluent in the Wits basin (Winde, 2009). Uranium is weakly radioactive as an alpha particle emitter, but because of the relatively high biological effectiveness of alpha particles within living cells its danger is multiplied many times if the emitter is ingested and stored in body tissue. Most ingested uranium is excreted, but even so its toxicity is also related to its heavy metal characteristics and is highly chemo-toxic and also now known as an endocrine disrupter (Raymond-Wish, 2007). Uranium toxicity increases when cadmium (Cd) is present. Exposure to high levels of uranium in groundwater near Kenhard in the Northern Cape is associated with the high incidence of leukaemia in that area (Winde, 2009). Exposure to uranium decay products, including radon gas, definitely poses significant health threats.

Wits Basin

The Wits basin (the geological unit) has been mined for over a century and the resulting void space is now huge. Some 120 mines have resulted in some 400km^2 of mine tailings (slimes) dams and about 6b tons of pyritic tailings (Winde, 2009). The AMD problem is also an unfortunate circumstance of geology. Water-filled and highly permeable Malmani dolomites overlie the quartzites of the gold-bearing reefs. Fractures allow water to flow from the dolomites into the mine workings. For years, a significant operational cost of the gold mines has been the continuous dewatering of the mines. These same fractures and pathways are now responsible for the ingress of water into the closed and abandoned mines, as well as AMD egress into surrounding aquifers and even into surface waters.

Many of the mines in the Wits basin are interconnected, but they are grouped by relatively impermeable dykes and faulting into four major compartments, *viz*, the Eastern Basin (East Rand), Central Basin (Johannesburg), Western Basin (West Rand) and Far Western Basin (Carltonville). Unmanaged, the Wits basin goldfields have the potential to produce 350 000m^3 of AMD effluent per day (Manders *et al*, 2009). Water began decanting from the Western Rand in 2002 and now produces 15.7Ml (megalitre) per day, at the old Swartrif shaft near the Epol plant in Randfontein. This water now causes pollution in the Krugersdorp Game Reserve and flows past the Cradle of Humankind national heritage site. Partial treatment of the water is already underway.

In the Central Basin current water levels are about 500m below surface, rising at 0.5m per day. In the Eastern Basin, decant is expected in three years if no remedial action is taken. Grootvlei mine is the last major mine operational in the area and pumping has ceased because of the mine's financial problems. Water is rising at 15-18m per month. The critical level is apparently 150m below the surface at South West Vertical shaft at East Rand Proprietry Mines (ERPM). Urgency is required because of the time it takes to place infrastructure into position to mitigate the problem. To add urgency to the problem, the uncharacteristically heavy rains of the 2010/2011 rainy season have exacerbated the ingress of water into the mines and the rate of decant, from both mines and tailings dams. The total mine void is largest on the Far West Rand. Uncontrolled AMD decant from this compartment will create substantial future challenges for Potchefstroom when the deepening mines are played out.

The Tweelopiespruit and Blaawbankspruit flow north from the Western Basin into the Crocodile River system and eventually Limpopo system. Both are now polluted. Blesbokspruit and Klip River draining into the Vaal from Central Basin face declining water quality in the future if and when the Critical Environmental Level (CEL) is reached. CEL occurs when acid water reaches the dolomites (which are chemically erodible by the acid waters) and pollutes groundwater systems. Wonderfonteinspruit is highly polluted with uranium, as is Robinson Lake. In an investigation (known as the Brenk Report) by the National Nuclear Regulator (NNR), Robinson Lake was determined to be a radiological hazard, but the details of its findings on proposed government responses, are confusing.

Management responses

The problem of AMD and the future of the Wits basin gold mines has been recognised since 1996 and a mine-water decant model has been developed by various geohydrologists. Mining plans for

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every single shaft exist, allowing calculations of underground void volume, which varies with depth. Recharge is calculated by measuring the rate of water rise (working backwards from volume and measured rise of water level).

Plans for control of water levels include pumping water across from Eastern and Western basins and putting this into groundwater storage in the Central Basin, from where it can be pumped via ERPM's South-West Vertical (SWV) Shaft just south of Germiston's CBD into a large treatment plant and then discarded (Germiston is in the Central Basin). This is a favoured site because it is located next to a large old purification plant that went out of operation in 2008.

Political solutions

The constant media coverage, the pollution in the Western Basin and the evident rising water levels in all four Wits basins pointing to future problems, has put pressure on the South African government and the mining industry for a response. The Western Utilities Corporation (WUC) proposal is an industry response - water would be purified to an acceptable standard and sold to water utilities as potable water, with sales used to defray costs and be profitable. The process used would allow recovery and reuse of the prime reactants. The government appears not to like this approach. Minister in the presidency, Trevor Manuel, warned that there were private sector interests driving this agenda.

Government commissioned a study on risk mitigation and water treatment, using experts from government departments, parastatals and universities. This study was presented to parliament on 21 February 2011. It acknowledged the seriousness of the situation but downplayed the urgency for rapid response and countered some of the 'hype' generated in the public mind. The report notes that the water level is still 700m below the CEL in the Eastern Basin, 480m in the Central Basin and that the matter is not as urgent as it first seems. Pumping in the Central Basin is planned to begin in March 2012, in time, so the report implies, to prevent the most serious of the outflows. This view is at odds with a model developed by independent scientists – who predict decant some time in 2012 at the Cinderella East shaft, Rondebult Road near Boksburg decant rate ~57Ml per day (57 000m^3/day or 660l per second) (De Lange, 2010). The problems of decant in the Western Basin are acknowledged in the government report and the focus of remedial activities would start there.

The report apparently says little about a cost recovery except to note that current mine owners will be approached to contribute to the costs of infrastructure and operation, as well as the possibility of the collection of an 'environmental levy' to fund operational costs. There is disagreement about who is responsible for dewatering defunct mines and treating the polluted water. Individual mines still operating when all others around them have closed (last-man standing syndrome) are overwhelmed by the quantity of water entering the operating mines and cannot cope with the financial demands of pumping and treatment. Liming of the acidic waters results in the precipitation of metal rich and radioactive sludge in ponds, where it becomes a secondary source of pollution.

Meanwhile, uranium levels in water samples have increased substantially over the last two decades in the Western Basin (Winde, 2009). Disconcertingly, effluent containing dissolved uranium ends up in karstic groundwater systems in the Boskop Turffontein Compartment that is the major source of water for Potchefstroom. In areas where there is a high incidence of poverty, other health stressors are usually found, which include higher rates of malnutrition, air pollution and poor water quality that includes bacteriological pollution. The understanding of how heavy metal toxicity affects people whose health is also compromised by the above factors, combined with the high incidence of HIV/AIDS is not well understood, except that tolerance of heavy metal poisoning is much lower (Winde, 2009). At the same time, the population in the affected areas continues to increase.

Experts do not know how long the problem could last. Prof T McCarthy at Wits University believes that once the surface layer of water in the mines has flushed through several times there will be a reduction in acidity as only the top layers of water will circulate through (percolating into the old

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works from the tunnel ceilings and then recycling back out), so that deep mine water does not mix and circulate, thereby sterilising that water. This theory does not take into account possible overturning of the water by heatflow convection from deeper within the mine.

The future

AMD is persistent and very difficult to rectify once established (Oelofse & Turton, 2008). The problem is here to stay and is expected to worsen. Ingress of water into old workings cannot be prevented nor can acidic outflows from these voids. There is a huge extant volume of pyritic tailings that will continue to leak acidic, iron and sulphate-rich waters for centuries. Plumes of sulphate-enriched groundwater will continue to expand and pollute important groundwater and surface water resources, unless water levels are controlled below the critical environmental level. The only feasible solution is to manage the situation as sustainably as possible, which also means treating the water to acceptable standards and selling it to local water utilities as a means of cost recovery. The 'do nothing' option will result in expanding environmental problems across southern Johannesburg and into the headwaters of the Vaal River catchment, which is not viable.

It is clear that the legacy of a century of gold and coal mining amounts to hundreds of millions of rands per annum in costs to the environment and mitigation. The increasing problems emanating from disused coal workings that are already affecting water quality in the Olifants River catchment will also need to be addressed. It needs to be kept in mind that prospecting rights are being granted across 43% of the area of Mpumulanga – mostly for coal on the Highveld, with implications for the future generation of AMD (Salgado, 2011). Coal mining is also expanding into the Waterberg area and the potential generation of AMD will have an additional locus. It should strongly be kept in mind that South Africa as a developing country is also developing water scarcity. Pollution of the water resource multiplies that scarcity and AMD generated in the Wits basin and Highveld coalfields has an effect on the headwaters of major river catchments. It is a situation that the country can ill afford.

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