Commentary
Air quality risks pertaining to tailings storage facilities within the Witwatersrand Goldfields

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President Nelson Mandela at the 104th Annual General Meeting of the South African of the Chamber of Mines on the 8th of November 1994 announced that: "*South Africa is blessed with a special geological heritage. As such, the mining industry has been the bedrock of the South African economy for more than a century*".

Mining also creates residuals (tailings). Research has shown that tailings particles showed inherent in vitro toxicity based on physicochemical properties (Andraos & Gulumian, 2021).

Mine tailings are stored in Tailings Storage Facilities. Tailings Storage Facilities (TSFs) are engineered structures that are designed to contain tailings (residue following the extraction of valuable material from metal ore processing) and to manage associated water. TSFs are among the largest dams and structures in the world and will stand in perpetuity.

The Witwatersrand has been mined for more than a century. It is the world's largest gold and uranium mining basin with the extraction, from more than 120 mines, of 43 500 tons of gold in one century and 73 000 tons of uranium between 1953 and 1995, which led to a legacy of some 400 km^2 of TSFs and 6 billion tons of pyrite tailings containing 600 000 tons of uranium (Chevril et al, 2008).

Pollution related to Witwatersrand TSFs poses a number of hazards to surrounding communities. The major primary pathways by which contamination can enter the environment from TSFs are:

- the airborne pathway, where radon gas and windblown dust disperse outwards from mine sites,
- the waterborne pathway, either via ground or surface water or due to direct access, where people are contaminated,
- or externally irradiated after unauthorized entry to a mine site,
- by living in settlements directly adjacent to TSFs or in some cases, living in settlements on the contaminated footprints of abandoned mines (Sutton, 2007).

The Department of Agriculture and Rural Development in its 2011 Report, titled "*Feasibility Study on Reclamation of Mine Residue, Areas for Development Purposes: Phase II Strategy and Implementation Plan*" also identified air-quality, with particular reference to dust pollution from TSFs (including radioactive dust) as one of the three main issues relating to TSFs within the Witwatersrand (Department of Agriculture and Rural Development, 2011).

Dust concentrations of up to 3 700 mg per m^3 of air were reported from areas adjacent to TSFs of the East Rand during a windy day (Coetzee et al, 2006).

Hazards relating to the airborne pathway include particulate matter (PM_{10} and $PM_{2.5}$), total suspended particulates, dust fall, silica quartz, iron pyrite and elements with concentrations higher than the average crustal soil such as gold, arsenic, lead, mercury, cyanide, etc. (Annegarn, 2021).

With reference to dust fall, the National Dust Control Regulations of 1 November 2013 prescribe a dust fall rate for residential areas of no more than 600 mg/m^2 per day, with a permitted frequency of two exceedances within a year but not in sequential months. Dust fall within non-residential areas may not exceed 1200 mg/m^2 per day, with a permitted frequency of two exceedances a year, not in sequential months. A residential area is defined as an area classified for residential use in terms of the local town planning scheme while a non-residential area is defined as an area not classified for residential use in terms of the local town planning scheme. The National Dust Control Regulations do not include any penalties for exceedances. Penalties only apply to a failure to prepare, submit and implement an air quality management plan.

The proposed amendments to the National Dust Control Regulations of 2023 will require mining operations to develop and submit a dust management plan to an Air Quality Officer for approval **prior** to commencement of the operation or activity and not only if there were exceedances. Furthermore, the proposed amendments now include in its definition of "residential area", informal settlement areas, where no zoning is in place (Department of Forestry, Fisheries and Environment, 2023).

Notwithstanding Regulations 17(6) to 17(10) of the Mine Health and Safety Act Regulations, under the heading "*Safety Precautions*", which prescribe a horizontal distance (buffer zone) of 100 metres from "*dams, waste dumps or any other structure whatsoever including structures beyond mining boundaries*" and the Department of Mineral Resources and Energy's rule

to extend the prescribed 100 metres to 2 000 metres, housing developments, both formal and informal, continue to encroach onto land close to TSFs (Department of Mineral Resources and Energy, 2015). The housing and population sprawl near TSFs in the Witwatersrand is exacerbating human exposure to windblown dust (Kneen et al, 2015).

Analysis of monitoring campaign data has confirmed multiple occurrences of quartz rich inhalable dust in residential settings at levels that exceed occupational health standards. Research by Kneen et al. (2015) indicates that the finer milling used for modern gold extraction results in aeolian dust emanating from the TSFs, which contributes to a higher proportion of inhalable particles in the source material. Air quality dispersion modelling, validated by ambient aerosol monitoring campaigns, indicates that episodic dust events generate particulate matter (PM_{10}) and, specifically, quartz dust concentrations that are unhealthy at distances of up to 2 km downwind from TSFs (Kneen et al, 2015).

As a consequence of the uraniferous nature of the ore, Witwatersrand tailings often contain significantly elevated concentrations of uranium and its daughter radionuclides, with the decay series of U^{238} being dominant. Mining has resulted in the dispersal of radioactive material into the environment via *inter alia* windblown dust (Coetzee & van Tonder, 2008).

The eastern catchment of the Mooi River, also known as the Wonderfonteinspruit, has been identified in a number of studies as the site of significant radioactive and other pollution, generally attributed to the mining and processing of uraniferous gold ores in the area. An assessment of radiological impacts of mining activities in the Wonderfonteinspruit Catchment Area (WCA)[1] was carried out on behalf of the National Nuclear Regulator (NNR)[2] by BS Associates in 2007.

Although the potential radiation exposures caused by emissions of radon and contaminated dust from mining legacies were outside the scope of the investigations, it was found that "*significant radiation exposure can occur in the surroundings of mining legacies, due to:*

- *Inhalation of Rn-222 daughter nuclides from radon emissions of desiccated water storage dams and slimes dams.*
- *The inhalation of contaminated dust generated by wind erosion from these objects, and*
- *The contamination of agricultural crop (pasture, vegetables) by the deposition of radioactive dust particles, which can cause considerable dose contributions via ingestion.*

"Due to the small particle size of the slimes, particulate matter can be transported over relatively long distances to agriculturally used land in the surroundings… the deposition of radioactively contaminated dust on leaves of vegetable and forage plants can cause radiation exposures exceeding those from the "inhalation of contaminated dust" substantially, being in the order of dose contribution of the so-called 'water pathways'" (National Nuclear Regulator, 2007).

In any pollution scenario, it is important to understand the risk posed by the pollution to the local human population hence it begs the question: how dangerous is uranium and its radioactive progeny to human health? High confidence scientific research has found that uranium is capable of spontaneously giving off energy and particles that can break chemical bonds and damage living cells – this property is termed radio-toxicity. Alpha emitters, once deposited inside the body can irreparably damage adjacent tissue and result in mutagenic defects and other malign transformations. In the light of new findings, uranium apart from kidneys, attacks the brain, acts as an endocrine disruptive compound by mimicking oestrogen (with possible consequences for the foetal development), compromises the immune system and damages the DNA (Brugge & Buchner, 2011; Institute de Radioprotection et de surete nucleaire, 2005; Zaire et al, 1997).

With reference to the health effects of the inhalation of uranium particles, research has found that small particles are carried by the inhaled air stream all the way into the alveoli. Here the particles can remain for periods from weeks up to years depending on their solubility. Highly insoluble uranium compounds may remain in the alveoli, whereas soluble uranium compounds may dissolve and pass across the alveolar membranes into the bloodstream, where they may exert systemic toxic effects. In some cases, insoluble particles are absorbed into the body from the alveoli by phagocytosis into the associated lymph nodes. Insoluble particles may reside in the lungs for years, causing chronic radiotoxicity to be expressed in the alveoli (Coetzee et al, 2004).

Stormwater drainage systems, into which windblown dust from adjacent slimes dams is flushed by run-off from sealed surfaces are also likely to constitute a major source of potential water pollution. Based on conservative assumptions regarding the affected surface area and average deposition rates of dust from adjacent slimes dams, it was estimated that approximately 10 tons of particle-bound uranium per year are flushed by stormwater into receiving watercourses (Coetzee et al, 2006).

In the light of the abovementioned findings, it logically follows that tailings storage facilities and tailings within the Witwatersrand goldfields represent a significant risk to local communities and ecosystems, especially in downwind and

[1]The Wonderfonteinspruit Catchment Area is a densely populated area and is extensively used for irrigation of edible crops, watering of cattle, spiritual rituals such as baptisms, recreational and domestic use and at times for drinking purposes due to the erratic supply of water (Liefferink, 2015)
[2]The NNR is mandated to provide for the protection of persons (the public and workers), property and the environment against nuclear damage as the competent authority for nuclear regulation in South Africa

downstream environments. It is therefore incumbent upon mining companies within the Witwatersrand to prevent the airborne risks associated with tailings and tailings storage facilities; to implement best practices in the design, construction, operation, maintenance, monitoring and management of the tailings storage facilities through all phases of a facility's lifecycle, including care and maintenance, decommissioning, closure and post-closure; and to disclose relevant information to communities at risk to support public accountability.

During the South African Human Rights Commission's (SAHRC) National Hearing on the Underlying Socio-Economic Challenges of Mining Affected Communities in South Africa in 2016 and the SAHRC's consultations with affected communities one of the most crucial factors raised with respect to environmental impacts was the increased levels of dust and the impact of these factors on food security, health, and overall conditions of well-being.

Pursuant to the SAHRC's National Hearing, the Commission issued the following directives to the relevant organs of state:

- The Department of Environmental Affairs (DEA) (now the Department of Forestry, Fisheries and Environment), in cooperation with the Department of Cooperative Governance and Traditional Affairs (COGTA) and the South African Local Government Association (SALGA), is directed to conduct an audit of all provincial governments and municipalities to confirm:

a. Whether all municipalities have developed and incorporated an air quality management plan into their Integrated Development Plans; and

b. Whether all provincial Members of the Executive Council and municipalities have appointed an air quality officer in line with the National Environmental Management Air Quality Act (NEMAQA).

- Noting the reported lack of certainty around the applicability of NEMAQA to mining activities, the Department of Mineral Resources (DMR) (now the Department of Mineral Resources and Energy) together with the DEA are directed to issue a formal notice clarifying the requirements. A copy of this public notice must be submitted to the SAHRC within three months from the release of this Report and must be accompanied by a report outlining measures taken to ensure that all industry role players are adequately made aware of the requirements.
- The DEA and DMR must jointly report on the measures taken to streamline the control of the cumulative air pollution impacts of mining operations. This report must outline the mechanisms that have been put in place for collation, verification and dissemination of information between stakeholders in relation to impacts reported and/or interventions undertaken in relation to air quality.

It is imperative that the SAHRC, whose Constitutional Mandate requires it to promote respect for human rights and a culture of human rights; promote the protection, development and attainment of human rights; and monitor and assess the observance of human rights in the South Africa, to ensure the compliance of the above-mentioned directives by the relevant organs of state, and in the absence of which, to legally enforce non-compliances. After all, Section 24 of the Constitution of the Republic of South Africa enshrines the right of "*everyone … to an environment that is not harmful to health and well-being*" (The Constitution, 1996).

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