Dispersion of Heavy Metals and their potential Impacts on the Environment: A case study of GoldTailings Dams in Giyani Belt, Limpopo Province, South Africa

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Abstract A study conducted at the Osprey and Fumani gold tailings dams indicated high concentrations of As (ppm) -7,824, Zn-96.4, Cu-64.2, and Cr-269.3. As was also high in soil, up to 4,183.3 ppm. The pH values were 4.0—3.3 in tailings dams and 7.4—3.2 in soils. High concentrations of these metals have toxicity potential on plants, animals and humans. For example, As content of 100 ppm in soil can reduce crop yield by 90% and lead to As food poisoning, resulting in skin and lung cancer, and even cardiovascular disease and diabetes. The study recommended the rehabilitation of these mine tailings.

Key Words Fumani mine, Tailings dams, Heavy metals, Environmental impacts

Introduction

Gold mining activities generally take place in relatively small areas, but can have great impacts on the environment. Tailings material can contain quantities of heavy metals found in the host ore, and added chemicals used in the extraction process. Elements are rarely in elemental form, more often they occur as complex compounds (Davies and Rice, 2001). Heavy metals occur naturally in the environment, however, concentration levels are greatly increased as a result of mining due to exposure to processes of weathering and erosion. Lead (Pb), Zinc (Zn), Copper (Cu), Arsenic (As), Cobalt (Co) and Cadmium (Cd) are the most common heavy metal pollutants due to mine waste generation. Heavy metals become toxic when they are not metabolized by the body and accumulated in the soft tissues. They enter the body through breathing, ingestion or through the skin. Consequently, there is need to determine the levels of heavy metals from mine wastes and their distribution on the environment. The current study focused on two mine sites, the Osprey and Fumani gold mines in the Giyani greenstone belt in the Limpopo Province of South Africa.

The nature and character of the heavy metals dispersed on the environment is generally determined by the mode of mineralisation within a given geological setting. The Giyani greenstone belt located at the northern margin of the Kaapvaal Craton had a number of small gold mines, including the Osprey and Fumani mines. The belt is 15 km wide and 70 km long, trending in the northeastern direction. Gold mineralisation was concentrated along the northwestern margin of the belt and is linked to the north - dipping ductile shear zones. Gold occurs preferentially in iron formation, in quartz and carbonate veins (Brandl et al., 1997), but also in quartzite, schist and amphibolites in contact with the granite-gneiss (Viljoèn et al., 1978). Gold mineralisation was controlled partly by folding, which concentrated it in fold hinges and troughs. It is generally associated with sulphide minerals, mainly arsenopyrite (FeAsS), pyrite (FeS_2), chalcopyrite ($CuFeS_2$), sphalerite (ZnS) and pyrrhotite (FeS).

About 10 tons of gold were recovered from four mines; Osprey, Fumani, Klein Letaba and Birthday (Brandl et al., 2006). The Fumani Mine was operational from 1933 to 1961 and was reopened in 1977 up to 1991. About 280,000 tons of ore with an average grade of 4 g/t Au were recovered. Gold occurred predominantly in steeply inclined quartz lodes and in mineralised schist and banded ironstone situated close to the contact with the granite-gneiss (Collins,1991). Gold is texturally associated with a sulphur-rich arsenopyrite in garnetiferous, biotite-rich bands.

Osprey Mine Tailings Dam

Six samples were collected from the tailings dams and 13 soil samples from around and away from the dams. The atomic absorption spectrometer was used to analyze Pb, Zn, Cu, As, Co and Cr in the samples. Tailings dam A had concentrations of (ppm): 4 Pb, 51 Zn, 92 Cu, 20 As, 54 Co and 290 Cr (Fig. 1), while dam B recorded concentrations of (ppm): 5 Pb, 56 Zn, 162 Cu, 14 As, 64 Co and 323 Cr (Fig. 2).

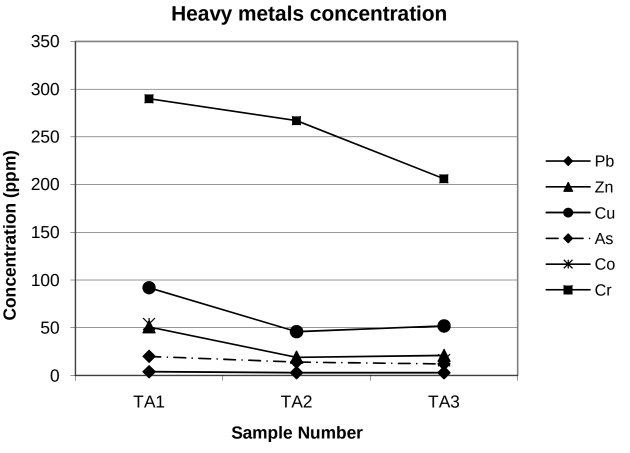

Figure 1 *Concentration levels of heavy metals in tailings dam A*

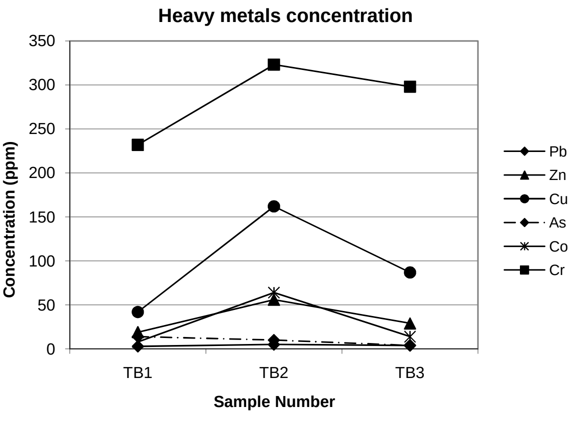

Figure 2 *Concentration levels of heavy metals in tailings dam B*

Both dams were found to be highly contaminated with these metals. The highest concentrations of Pb, Zn, Cu, As, Co and Cr in soil samples were (ppm): 6 at location SS6; 35 at SS7; 196 at SS8; 28 SS13; 36 at SS9; and 294 at SS3 respectively. The pH values for the tailings material and soil samples ranged between 3.99 – 3.50 and 7.39—4.11 respectively.

Fumani Mine Tailings Dam

Sampling of the tailings material was conducted over the three tailings dams (A,B, C) (9 samples) and soil samples were collected in the northern direction of tailings dam C and to the northeastern direction of tailings dam A (8 samples). The samples were analysed for Pb, Zn, Cu, As and Cd, using AAS. The paste pH of the samples was determined.

The average concentrations of Pb, Zn, Cu, As, and Cd at dams A, B and C were (ppm): 20.2, 96.4, 64.2, 7,824.0, and 1 respectively. However, arsenic was found to be particularly high with concentrations of up to 11, 236 ppm at tailings B. Zinc also registered maximum value of 134 (ppm) at tailings A. Judging from the metal values, this deposit was mainly a gold-sulphide deposit enriched in arsenic, zinc and copper. Gold was mainly associated with arsenopyrite (FeAsS). The average concentrations of Pb, Zn, Cu, As and Cd in soils were (ppm): 6.3, 36.0, 65.5, 309.5 and 1.0 respectively, northwards from tailings dam C; and 15.4, 50.3, 46.5, 4,924.8 and 1.0 respectively, to the northeast from dam A. There was general decrease in the concentration of heavy metals away from the tailings dams in the northern direction. For example, the concentration of As in this direction showed a downward trend away from the dam. The distribution of heavy metals in this direction can apparently be attributed to wind erosion as the land deeps southwards, thus water erosion is not possible. Paste pH measurements of tailings material indicated acidic conditions with average pH of 3.3—3.5 in tailings dams and 5.5 – 3.2 in soils.

Heavy metals toxicity

The study established high concentrations of As in tailings dams of 7,824 ppm and in soil of 4,183.3 ppm. This is likely to result in As poisoning in the area through dust inhalation and food chain. Concentration of 100 mg/kg As in soil can reduce crop yield by 90% and lead to As poisoning resulting in skin and lung cancer (Harada, 1996). Other possible effects are cardiovascular disease and diabetes (Centeno and Finkelman, 2007).

Concentration of Zn was up to 96.4 ppm. This can lead to water contamination. Generally Zn content of over 15 mg/L of water is considered toxic and can result into renal damage. Deposition of Zn salts into fish gills can lead to their death (US EPA, 2009). Copper provides essential micronutrients to plants, animals and humans. However, Cu concentration in water of over 30mg/L results in liver, kidney and blood cells damage (DWAF, 1996).

Cr is a micronutrient, which is essential for carbohydrate metabolism in animals. Cr VI is more toxic than Cr III, wherein Cr VI concentration of more than 0.5 µg/ml is considered to have negative effect (Alloway and Ayres, 1997). Excessive ingestion of Cr VI is carcinogenic. Concentration of Cr in plants growing on mine spoil and various types of Cr waste are commonly in the range of 10—19 mg/kg (Alloway and Ayres, 1997). In the study area the concentration of Cr was up to 269.3 ppm. This can lead to dust ingestion and also result in food chain poisoning.

Conclusion

The Osprey and Fumani gold tailings dams indicated high concentrations of As (ppm) -7,824, Zn- 96.4, Cu-64.2, and Cr-269.3. Arsenic was also high in soil, up-to 4,183.3 ppm. The pH values were 4.0—3.3 in tailings dams and 7.4—3.2 in soils.

There is high potential for As, Zn, Cu and Cr poisoning in the study area through dust inhalation and food chain as the concentrations of these metals in the tailings dams and soil are above the acceptable levels. Arsenic is particularly high in tailings dams and soil. There is need to undertake rehabilitation of these tailings dams.

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