Dispersion of Metals at Louis Moore Gold Tailings Dam, Limpopo Province, South Africa

Khodani Matshusa[1], Jason S. Ogola[1], Klaus Maas[2]

[1] *School of Environmental Sciences, University of Venda, P/Bag X5050, Thohoyandou 0950, South Africa, matshusakhodani@yahoo.com, ogolaj@univen.ac.za*

[2] *Hochschule Ostwestfalen-Lippe University of Applied Sciences, Germany, klaus.maas@hs-owl.de*

Abstract

The study focused on the dispersion of metals within and around the Louis Moore tailings dam. The work involved sampling and analysis of tailings, soil, grass and cow-dung. As, Ni and Mn were high in both tailings and soil with maximum values (mg/kg) of 937 and 975 As, 583 and 416 Ni, 1161 and 680 Mn respectively. Maximum values of (mg/kg) 11 and 16 As, 41 and 46 Ni, 520 and 426 Mn were recorded in grass and cow-dung respectively. The study recommends rehabilitation of the tailings dam in order to control the dispersion of metals to the environment.

Keywords: Louis Moore, Tailings dam, Heavy metals, Human health

Introduction

Mining is one of the main source of metals dispersion into the environment. Development or promotion of new mining activities has to consider the potential environmental impacts associated with mining. Gold mining in South Africa has resulted in the construction of hundreds of tailings dams. The rehabilitation of tailings dams is becoming increasingly important, hence, they represent the world highest waste volume, ahead of industrial waste and household waste (Bjelkevik 2005). There are 5906 abandoned mines in South Africa (SAI 2009). In Limpopo Province there are approximately 729 abandoned mines. Gold mine tailings dams are the source of heavy metals contamination of soil and groundwater. Consequently there is need to determine the concentrations of Pb, Zn, Cu, As, Co, Ni, Cd, and Mn in order to develop a geo-environmental model which can help to predict their dispersion in space and time. Ecosystems threats from mining activities are dominantly due to acid mine drainage. Human health impacts of gold-sulphide wastes are generally associated with either the inhalation or the ingestion of metals. Ingestion may be in the form of drinking water. Some elements are essential to human health, but at elevated quantities, they become toxic. For example, Zn and Cu are considered to be pollutants in water because of their high toxicity to aquatic life, despite their relatively low toxicity to humans. Severe Co contamination is relatively uncommon but mining, smelting and industrial processing may all cause Co contamination (Nikkarinen et al. 2011). Previous studies revealed that gold miners had a number of arsenic-associated health problems, including excess mortality from cancer of the lung, stomach, and respiratory tract (Eisler 2004). Long term exposure to Ni-sulphide dust caused carcinogenic gneumonia disease (Ponavic et al. 2006). However, Cu is ubiquitously distributed and toxic only in high concentrations (Gzik et al. 2003). This study focused on the distribution of heavy metals within the Louis Moore tailings dam

and their dispersion around the mine site. The Giyani Greenstone Belt is situated in the far north-east corner of Limpopo Province, adjacent to Kruger National Park and 80 km southeast of Thohoyandou. The belt is a northeast (NE) trending feature, which is about 15 km wide and 70 km long (Johnson et al. 2006). The belt has contributed slightly more than 10 tonnes of gold. Out of more than 44 gold occurrences, only six principal deposits, Klein Letaba, Louis Moore, Golden Osprey, Franke, Fumani, and Birthday mines, had contributed more than 97% of the total declared gold (Ward and Wilson 1998). The Louis Moore tailings dam is currently not covered by vegetation thus is highly eroded. However, the eastern section is not eroded and is at a lower elevation compared to the western and middle sections of the tailings dam.

Materials and Methods

A total of 17 tailings samples were collected on top of the tailings dam. Soil sampling was extended outside the tailings dam in four directions, northeast (NE), southwest (SW), northwest (NW) and southeast (SE). A distance of 500 m was covered in each direction at a sampling interval of 100 m. A total of 20 soil samples each weighing 2 kg were collected using auger drill and shovel. A total of 10 grass samples were collected on top of the tailings dam (G1-G10) (tab. 1). Cow-dung samples were collected randomly (CD1-CD6); CD1 on top of the tailings dam, CD2-CD4 around the tailings dam, CD5 about 2 km NE of the tailings dam and CD6 about 5 km SW of the tailings dam (tab. 1). It was noted that cows were grazing on grass at the top of the tailings dam. The collected samples were digested using aqua regia and analysed for Pb, Zn, Cu, As, Co, Ni, Cd, and Mn by atomic absorption spectrometry. The results were compared with the South African Soil Quality Standards and Dutch ABC system (Steyn et al. 1996). The Dutch ABC system uses a three tier approach to determine if soil or water is contaminated. The first tier concentrations (A-values) are those concentrations below which the soil or water is probably not contaminated. The second tier (B-values) indicates concentrations above which there is a need for further investigation. The third tier (C-values) refers to concentration levels above which site clean-up is required.

Results and discussion

Concentrations of metals in the tailings dam ranged between (mg/kg): 28-142 Pb; 35-130 Zn; 11-96 Cu; 0-937 As; 12-48 Co; 68-583 Ni; 0-2 Cd and 305-1129 Mn. Fig 1 shows a general decrease of metal values from the western to the eastern section of the tailings dam except for As. This shows that the distribution of metals in the tailings was not homogenous, thus the material deposited on the eastern part of the dam had high content of As. However, this requires further investigation.

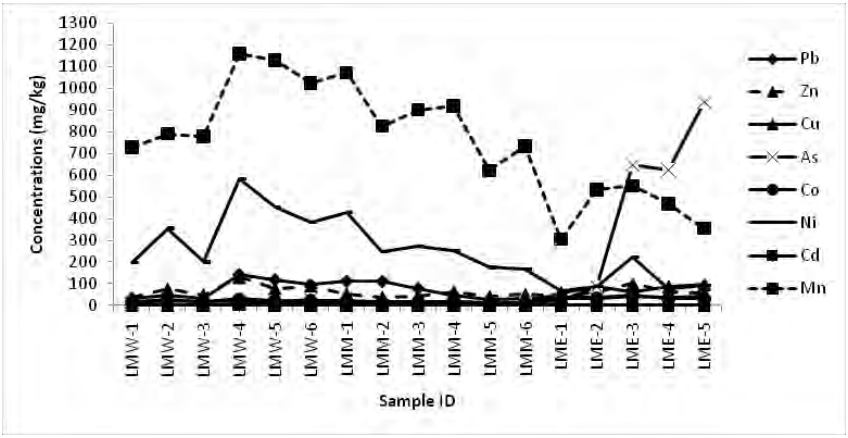

Figure 1 *Metals distribution of Louis Moore tailings: western section (LMW), middle section (LMM) and eastern section (LME).*

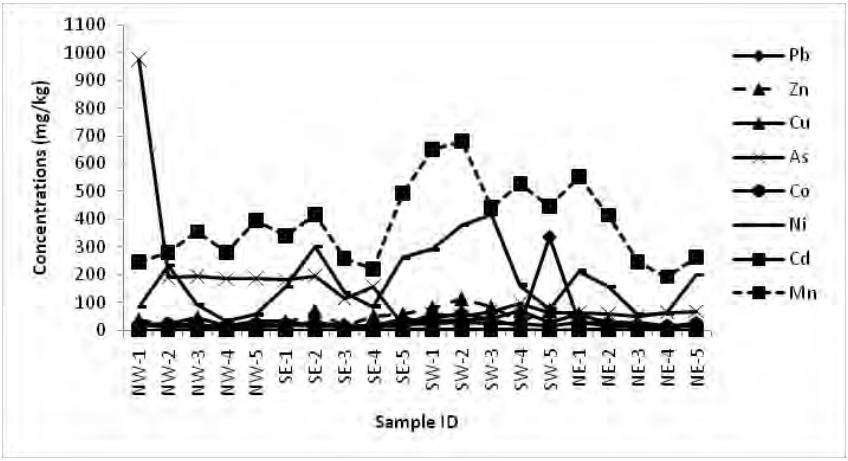

Figure 2 *Distribution pattern of metals in soil around Louis Moore tailings dam: north-west (NW), south-east (SE), south-west (SW), and north-east (NE) directions.*

The average concentrations of As and Ni exceeded the recommended Dutch B-values of 30 mg/kg and 100 mg/kg respectively, thus posing a potential risk to the environment and human health. In soil the concentrations were: Pb 8-37 mg/kg, Zn 11-112 mg/kg, Cu 15-70 mg/kg, As 20-975 mg/kg, Ni 34-416 mg/kg, Co 10-27 mg/kg, and Mn 192-680 mg/kg. Concentrations of metals in soil were rather variable (fig. 2). The maximum concentrations of As (974 mg/kg), Ni (416 mg/kg) and Mn (680 mg/kg) in soil exceeded the South African Soil Quality Standards of 2 mg/kg, 50 mg/kg and 330 mg/kg respectively, indicating contamination.

Table 1 *Metals concentrations in grass (G) and cow-dung (CD) within and around Louis Moore tailings dam.*

ID	Pb	Zn	Cu	As	Co	Mn	Ni
G1	5	11	11	0	0	258	35
G2	4	13	13	0	3	283	29
G3	15	86	14	0	2	520	41
G4	11	39	10	0	0	212	32
G5	9	19	20	0	2	497	30
G6	4	20	7	0	3	312	28
G7	3	14	28	6	2	228	16
G8	6	63	30	6	2	315	31
G9	6	16	32	11	1	115	25
G10	1	5	12	0	2	97	6
CD1	3	5	5	0	0	426	42
CD2	4	14	2	16	0	380	46
CD3	0	2	0	3	0	295	18
CD4	5	1	14	0	16	198	10
CD5	0	3	16	0	2	88	15
CD6	0	0	1	0	0	52	2

Concentrations of metals in grass ranged between (mg/kg): 1-15 Pb; 5-86 Zn; 7-32 Cu; 0-11 As; 0-3 Co; 97-520 Mn and 6-41 Ni. Concentrations of metals in cow-dung ranged between (mg/kg): 0-5 Pb; 0-14 Zn; 0-16 Cu; 0-16 As; 0-16 Co; 52-426 and 2-46 Ni. Maximum concentrations of metals in cow-dung were registered in samples collected around the tailings dams which suggest that cows grazing around the tailings dams were eating contaminated grass.

Conclusion

The study revealed that the Louis Moore tailings dam had concentrations of As (up to 937 mg/kg and Ni (up to 583 mg/kg) above the recommended Dutch B-values of 30 mg/kg and 100 mg/kg respectively. Due to un-rehabilitated tailings dams, the soil around the tailings dam has been contaminated by As, Ni and Mn, with maximum values up to 975 mg/kg, 416 mg/kg, and 680 mg/kg respectively above the South African Soil Quality Standards of 2 mg/kg, 50 mg/kg and 330 mg/kg respectively. The grass within and around the dam had maximum values of 520 mg/kg and 41 mg/kg for Ni and Mn respectively. The cow-dung within and around the dam had maximum values of 426 mg/kg and 46 mg/kg for Ni and Mn respectively.

Acknowledgements

The authors would like to thank NRF and the Federal Ministry of Education and Research (BMBF) of Germany for their financial support and the University of Venda and the Hochschule Ostwestfalen-Lippe University of Applied Sciences for supporting the implementation of the project. We express sincere thanks to Xstrata SA and the Council for Geoscience for the initial support of the project.

References

Bjelkevik, Annika. 2005. Water Cover Closure Design for Tailings Dams - State of the Art Report. [pdf] s.l. : Luleå University of Technology. ISSN 1402-1528 ISRN LTU-FR -- 05/19 -- SE.

Eisler, R. 2004. Arsenic hazards to human, plants, and animals from gold mining. Rev Environ Contam Toxicol, Vol 180, 133-165.

Gzik, A., Kuehling, M., Schneider, I. and Tschochner, B. (2003). Heavy Metal Contamination of Soils in a Mining Area in South Africa and its Impact on Some Biotic Systems. Journal of Soils and Sediments, Vol 3(1), 29-34.

Johnson, M.R., Enhaeusser, C.R. and Thomas, R.J. (2006). The Geology of South Africa. Council for Geoscience and Geological Society of South Africa, 34-36.

Nikkarinen, M., Kousa, A., Makkonen, S., Koivuhuhta, A. and Nerg, M. (2011). Environmental cobalt and health. Geological and Medical Sciences for a Safer Environment, 4th International Conference on Medical Geology GeoMed2011, Bari-Italy, 99.

Ponavic, M., Pasava, J., Vymazolova, A., Kribe, B., Deng, H., Lou, T., Li, C. and Zeng, M. (2006). Fractionation of toxic trace elements in soils around Mo-Ni black shale-hosted mines, Zunyi region, Southern China: Environmental implications. Bulletin of Geosciences, Vol 81 (3), 197-206.

SAI (2009). Report of the Auditor-General to Parliament on a performance audit of the rehabilitation of abandoned mines at the Department of Minerals and Energy.

Steyn, C.E., Van Der Watt, H.V.H. and Claassens, A.S. (1996). On the permissible nickel concentration for South African soils. South African Journal of Science, Volume 92, 359-363.

Ward, J.H.W. and Wilson, M.G.C. (1998). Gold outside the Witwatersrand Basin. In Wilson, M.G.C. and Anhaeusser, C.R. (eds.). The Mineral Resources of South Africa, 740.