Zimbabwe Journal of Science & Technology pp 111 – 115 Vol.14 [2019]
e-ISSN 2409-0360
Zimbabwej.sci.technol

Variation of heavy metal concentration in soil around a platinum slimes dam

Forster Nyimai and Never Mujere*

Department of Geography, Geospatial Science and Earth Observation, Faculty of Science, University of Zimbabwe, P O Box MP 167, Mt Pleasant, Harare, Zimbabwe
Email: nemuj@yahoo.co.uk

Abstract: Platinum mining contributes significantly in sustaining most national economies. While the global demand for platinum continues to rise, the release of waste from mining activities into air, water and soil has profound negative effects on food production, animal and plant health. This study evaluates spatial variations of iron (Fe), nickel (Ni), lead (Pb) and chromium (Cr) in soil around a slimes dam at Mimosa platinum mine in Zimbabwe. Five sets of soil samples were collected at a depth of 20 cm within an interval of 50 m from the foot of the slimes dam in the north, south, east and west directions. Soil samples were put in polythene bags and transported to the laboratory for analysis of heavy metal concentrations using the EDTA titration method. The findings show that concentrations of the four heavy metals show notable variations with increasing distance from slimes dam. This implies that sustainable waste management practices need to be put in place to reduce adverse environmental of heavy metal pollution in soils.

Keywords: Heavy metals, slimes dam, platinum, spatial variation, Mimosa
Received:31.10.21 **Accepted**:16.02.21

1. INTRODUCTION

Platinum mining contributes towards socio-economic transformation of many economies. Zimbabwe hosts 7% of the global platinum reserves after South Africa (68%) and Russia (16%) (World Bank, 2017; Fatoyi, 2020). In 2018, the country's platinum contributed 29% (after gold which contributed 45%) of the total mineral revenue value of US$2.5 billion (Zimbabwe Chamber of Mines, 2018). Nevertheless, the process of extracting valuable platinum minerals in the platinum group metal (PGM) industry generate large quantities of gaseous, solid and liquid wastes. Though some heavy metals are essential for normal life physiological processes, higher concentrations above stipulated levels have deleterious effects on human health and biota (Gzik, et al., 2003). Mine wastes are disposed as rock of unused extraction products stored in landfills, mine dumps, slimes, stockpiles or temporary dumps of materials selected by grade. Slag heaps comprise ash produced during cleaning furnaces or smoke stacks and tailings consist of large piles of crushed rock left after separating the value ore fraction from the worthless fraction. Tailings are deposited in slimes dams (Zaranyika and Chirinda, 2011; Olobatoke and Mathuthu 2016). Wastes released in an uncontrolled manner cause widespread adverse direct and indirect contamination of ecosystems (Fashola et al., 2016; Festin et al., 2019).

Several environmental studies have focussed on the impact of heavy metals from platinum mining activities on the quality of surrounding surface or ground water (e,g Gzik et al., 2003; Zobrist et al., 2009) and soil pollution at different depths (Maboeta et al., 2006; Nkobane et al. 2015). Little research work has been done on spatial variation of heavy metals in soils with increasing distance from slimes dams. It is critical to study diffusion of toxic metals in mine solid waste dumps to understand how the release of metal pollutants from mine solid waste dumps can be controlled.

This study therefore examines the variations nickel (Ni), chromium (Cr), lead (Pb) and iron (Fe) concentration in soil with distance from the platinum slimes dam at Mimosa Mine in Zimbabwe.

2. MATERIALS AND METHODS

2.1 Study area

Mimosa platinum mine (lat-long: 20.261°S, 29.82°E) lies along the Great Dyke at an altitude of 1053 m in the Midlands province of Zimbabwe (Figure 1). Its mining complex occupies a surface area of 5.69 km^2 of which almost 18% is covered by the slimes dam whose volume is 31,680,000 m^3 and its height is 30 m.

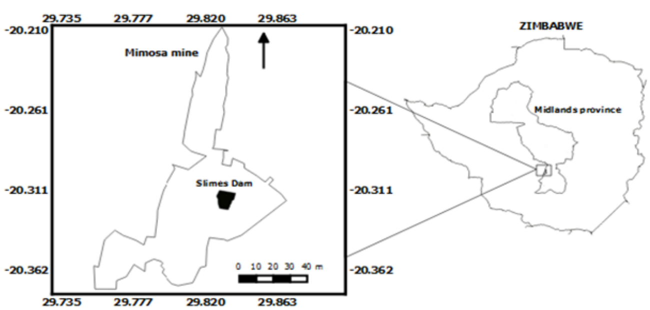

Figure 1. Location of Mimosa mine slimes dam in the Midlands province of Zimbabwe

The mine lies on a relatively gentle slope dominated by chromic luvsoils, lithic leptosols and rhodic cambisols. These soils are moderately shallow, brown or reddish brown clays; formed on mafic rocks (Oberthür, 2011). The Great Dyke is a layered intrusion of linear shape and strikes over 550 km NNE with a maximum width of about 11 km, cutting Archean granites and greenstone belts of the Zimbabwe craton. It is longitudinally subdivided into a string of narrow contiguous layered chambers and sub-chambers from north to south (Oberthür, 2011).

Mimosa mining area is covered by miombo woodland, comprising *Brachystegia Speciformis*, *Julbernadia Globiflora*, and *Terminalia Sericia* vegetation species. It lies in a semi-arid region which receives an average annual rainfall of 568 mm with a coefficient of variation of 25%. The dry season spans from May to September and experiences an average temperature of 20˚C. The average temperature during the wet season from November to April is 28˚C (Timberlake and Nobanda, 1993).

2.2 Soil sample collection

The area covered by Mimosa Mine slimes dam was digitized from Google Earth in Quantum GIS (QGIS) to create a polygon map. Four transects along the north, east, west and south of the slimes dam were also designed in QGIS.

Five sampling points were systematically chosen along each 200m transect from the edge of the slimes dam in the north, south, east and west directions. The sampling interval was 50m. A hand-held Garmin Global Positioning System (GPS) 62s was used to collect coordinates of the sampling points. A shovel was used to prepare the sampling area. An auger was used to drill and recover soil samples from a depth of 20cm at each sampling point.

A total of soil 20 samples were collected at a depth of 20cm in all the four directions from the slimes dam using a hand-held soil auger and shovel. Soil samples were packed, tagged and sealed in clean colourless polythene bags on site to avoid contamination. They were then stored in a cooler box and transported to the University of Zimbabwe's University of Zimbabwe's Geography and Environmental Science laboratory for heavy metal analysis within 48 hours.

2.3 Soil sample preparation and analysis

In the laboratory, soil samples were analysed for chromium (Cr), lead (Pb), iron (Fe) and nickel (Ni) concentrations using the EDTA titration method (Schwarzenbach and Flaschka, 1969). The soil samples were weighed on a calibrated balance and dried at 105°C in an oven for 24 hours. Dried samples were then weighed and put into a 500ml conical flask where 10ml of concentrated hydrochloric acid and nitric were added at a ratio of 3:1. The conical flask was covered with a small watch glass and the solution was heated in the fume hood to near dryness. We added 10ml of water to dissolve the residue and then transferred the solution quantitatively into a 100ml volumetric flask, and make up to the mark. The solution was used for subsequent analyses of lead, chromium, nickel and iron concentrations.

3. RESULTS

3.1 Variation of chromium concentration

The average concentration of Cr was 0.68 mg/kg in the west, 0.33 mg/kg in the east, 0.35 mg/kg in the south and 0.58 mg/kg in the north directions from the slimes dam.
The concentration of Cr is generally increasing from the foot of the slimes dam in the east, west and south directions while in the north direction it depicts a decreasing trend (Figure 2).

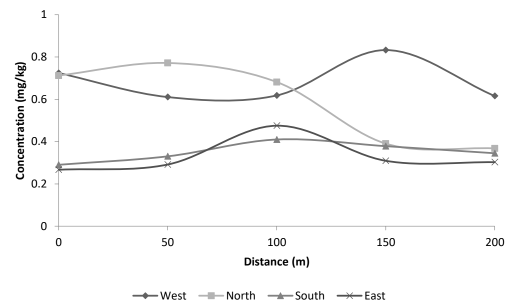

Figure 2. Variation of Cr concentration with distance from the edge of the slimes dam

3.2 Variation of iron concentration

The mean concentration of iron is 1.03 mg/kg in the west direction, 0.23 mg/kg in the east, 0.28 mg/kg in the south and 0.64 mg/kg in the north directions from the slimes dam. The concentration of iron is generally decreasing with increasing distance from the edge of the slimes dam in the western and northern directions. In the eastern and southern directions, iron concentrations increase from the edge of the slimes dam (Figure 3).

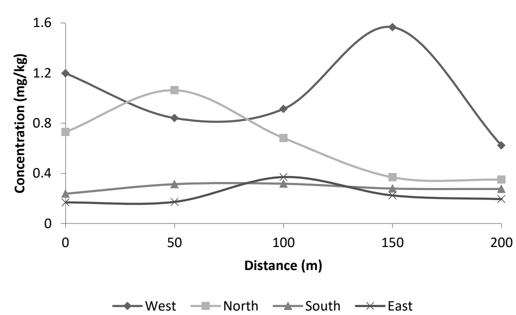

Figure 3. Variation of Fe concentration from the slimes dam

3.3 Variation of nickel concentration

The average concentration of nickel was 1.69 mg/kg in the west direction, 0.37 mg/kg in the east, 0.47 mg/kg in the south and 1.05 mg/kg in the north directions from the slimes dam. Nickel concentration decreases with increasing distance from the edge of the slimes dam in the western and northern directions while in the east and south directions it shows an increasing trend (Figure 4).

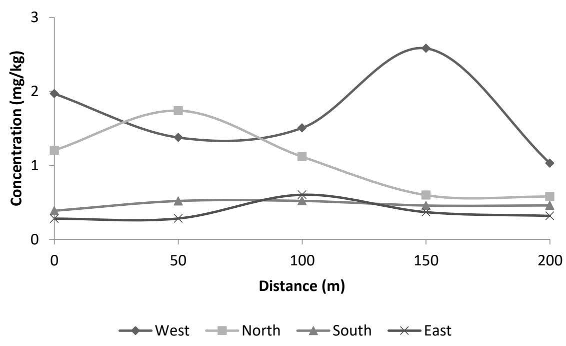

Figure 4. Variation of Ni concentration with distance from the slimes dam

3.4 Variation of lead concentration in soil

The average concentration of Pb was 0.34 mg/kg in the west and 0.21 mg/kg in the south directions from the slimes dam. The concentration of Pb generally decreases in the west direction while in south direction it is increasing distance from the edge of the slimes dam (Figure 5). The metal could not be observed in soil along north and east transects from the slimes dam.

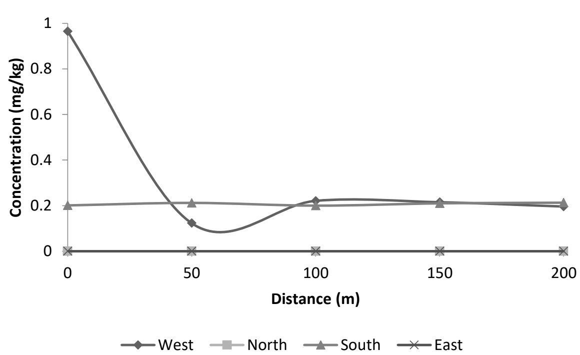

Figure 5. Variation of Pb concentration in all the four directions from the slimes dam

4. DISCUSSION

The study shows that the concentrations of heavy metals fluctuated with increasing distance from the slimes dam. It was observed that the concentrations of Cr, Fe, Ni and Pb increased with distance along the south transect from the foot of the slimes dam. Along the east transect, Cr, Ni and Fe also increased with increasing distance from the slimes dam. Pb concentration increased from the slimes dam along the west transect. The metal could not be observed in the north and east directions.

The concentration of Cr, Ni and Fe decreased with distance along the west and north transects. This variation is similar to the finding by Nkobane *et al*. (2015) who observed a decrease in the concentration of chromium with increasing distance from the mine dam in South Africa. Closer to the dam (source of contamination), there was higher concentration of heavy metal in the soil as compared to further away from the dam. A study by Olorunfemi (1984) also observed that the concentrations of lead, nickel, chromium and iron in soils reduce exponentially with increasing distance from the slimes dam. This was attributed to water movement as well as changes in topography.

The EDTA titrimetric method used in this study to determine the heavy metals concentration has some shortfalls with regards to interferences. Nevertheless, it gave a general picture of mineral concentrations.

5. CONCLUSION

Although mining provides social and economic benefits, its adverse effects on environment and public health cannot be overlooked. Mining has deleterious effects on the human health, land, water, fauna and flora. The objective of this study was to establish the spatial variations of Cr, Fe, Pb and Ni metals in soil in the vicinity of a platinum mine slimes dam at Mimosa mine in Zimbabwe. The soil samples were analysed to determine the contents of the four heavy metals studied using the EDTA titration method.

Results of this study give a snapshot view of the spatial variations of heavy metal soil pollution from the platinum mine slimes dam at Mimosa mine in Zimbabwe. These findings provide information useful for findings for managing slimes dams.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

AUTHORS' CONTRIBUTIONS

Each of the authors contributed to the development of the paper.

ACKNOWLEDGEMENTS

The authors are grateful to management staff of Mimosa mine who allowed the research to be conducted at the slimes dam in their premises.

REFERENCES

Fashola, M.O., Ngole-Jeme, V.M. and Babalola, O.O. 2016. Heavy metal pollution from gold mines: Environmental effects and bacterial strategies for resistance. *Int. J. Environ. Res. Public Health*, 13(11), 1047-1067.

Fatoti, A. 2020. Africa's economic transformation and global value chains. *Africa Development*, 45(1):163-180.

Maboeta, M.S., Claassens, S., van Rensburg, L. and van Rensburg, P.J.J. 2006. The effects of platinum mining on the environment from a soil microbial perspective. *Water Air and Soil Pollution*, 175(1-4):149-161.

Nkobane, M. P., Afolabi, A. S. and Abdulkareem A.S. 2015. Evaluation of heavy metals in platinum tailing dam site. *Proceedings of the World Congress on Engineering*, Vol. II July 1-3, London, U.K.

Oberthür, T. 2011. Platinum-group element mineralization of the main sulfide zone, Great Dyke, Zimbabwe. In*: Reviews in Economic Geology, Society of Economic Geologists*, Germany, Edition 17, Chapter 12, 329–349.

Olobatoke, R.Y. and Mathuthu, M. 2016. Heavy metal concentration in soil in the tailing dam vicinity of an old gold mine in Johannesburg, South Africa. *Canadian Journal of Soil Science*, 96(3): 299-304.

Schwarzenbach, G. and Flaschka. H. 1969 *Complexometric titrations*. Methuen. London.

Timberlake, J. and Nobanda, N. 1993. Vegetation survey in Zimbabwe. Kirkia, (14(1): 24-48.

World Bank, 2017. *The growing role of minerals for a low carbon future*. World Bank, Washington DC, USA.

Zaranyika, M.F. and Chirinda, T. 2011. Heavy metal speciation trends in mine slime dams: A case study of slime dams at a gold mine in Zimbabwe. *Journal of Environmental Chemistry and Ecotoxicology*, 3(5): 103-115.

Zimbabwe Chamber of Mines 2018. *State of the mining industry report. Prospects for 2019*. Zimbabwe Chamber of Mines, Harare.

Zobrist, J., Sima M., Dogaru, D., Senila, M.,Yang, H., Popescu, C., Roman, C., Bela, A., Frei, L., Dold, B. and Balteanu, D. 2009. Environmental and socioeconomic assessment of impacts by mining activities-a case study in the Certej River catchment, Western Carpathians, Romania. Environ. *Sci. Pollut. Res. Int*., 16(1): 14-26.