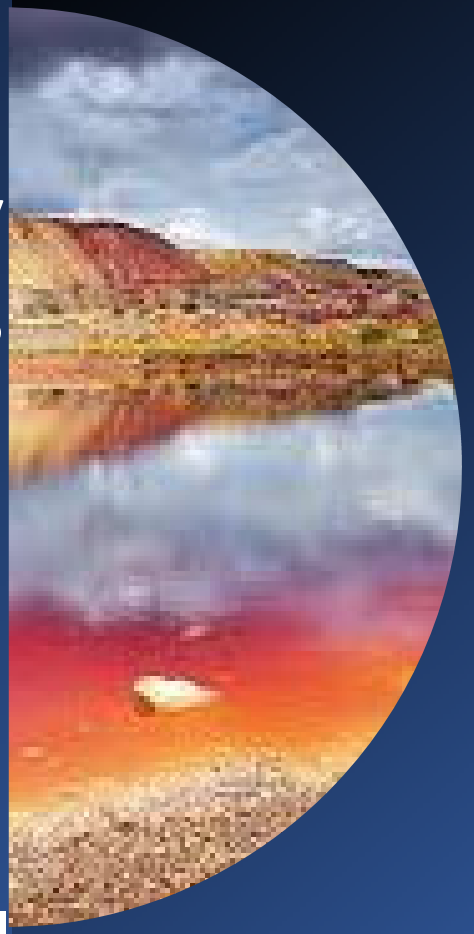
The transport of toxic elements from the Marie-Louise landfill site and nearby gold mine dumps to waterbodies

Dr. Alseno Kagiso Mosai
Prof. Heidi Richards
Prof. Hlanganani Tutu



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

WVTF IMWA 2024

West Virginia Mine Drainage Task Force Symposium &
15th International Mine Water Association Congress
April 21–26, 2024 | Morgantown, WV, USA

Outline

- Introduction
- Aims and objectives
- Methodology
- Results
- Conclusions
- References

Introduction

Waste generation has been increasing over the years

- increasing population,
- urbanisation,
- new technologies,
- growing industries

Many countries in various parts of the world are struggling with waste management

- Presence of toxic components.

Landfilling especially open dump landfilling is the cheapest and most widely used waste disposal management in many countries.

Issues associated with landfills

- large space requirement,
- leachate generation,
- biogas generation and
- bad odour as well as air pollution leading to sanitary issues.

Introduction

Developed and developing countries use engineered landfills which are more sustainable and have less impact on the environment during the early stages.

- aging of these landfills normally leads to severe environmental consequences, similar to uncontrolled landfills.

Closed and abundant landfills have a negative effect on the environment.

Open landfills are not regulated and often lack planning hence, susceptibility to:
- uncontrolled burning,
- scavengers,
- disease vectors and
- toxic elements.

It is also important to know the fate of toxic pollutants in landfill sites.

This will help determine the most suitable treatment required especially in landfills that have been operating for many years without the consideration of pollutant migration into the environment.

Thus, constant monitoring of landfills is required. Moreover, the removal and management of toxic elements in landfills is crucial.

Toxic elements (Cd, Cu, As and Pb) normally detected in landfill sites

Introduction

Mining has been the backbone of the economies of many countries for many years.

Mining operations

Waste

Waste

Acid mine drainage

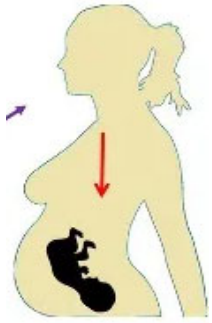
Mine dumps

Waste contains different toxic elements

Transport to waterbodies

Surface Water

Ground Water



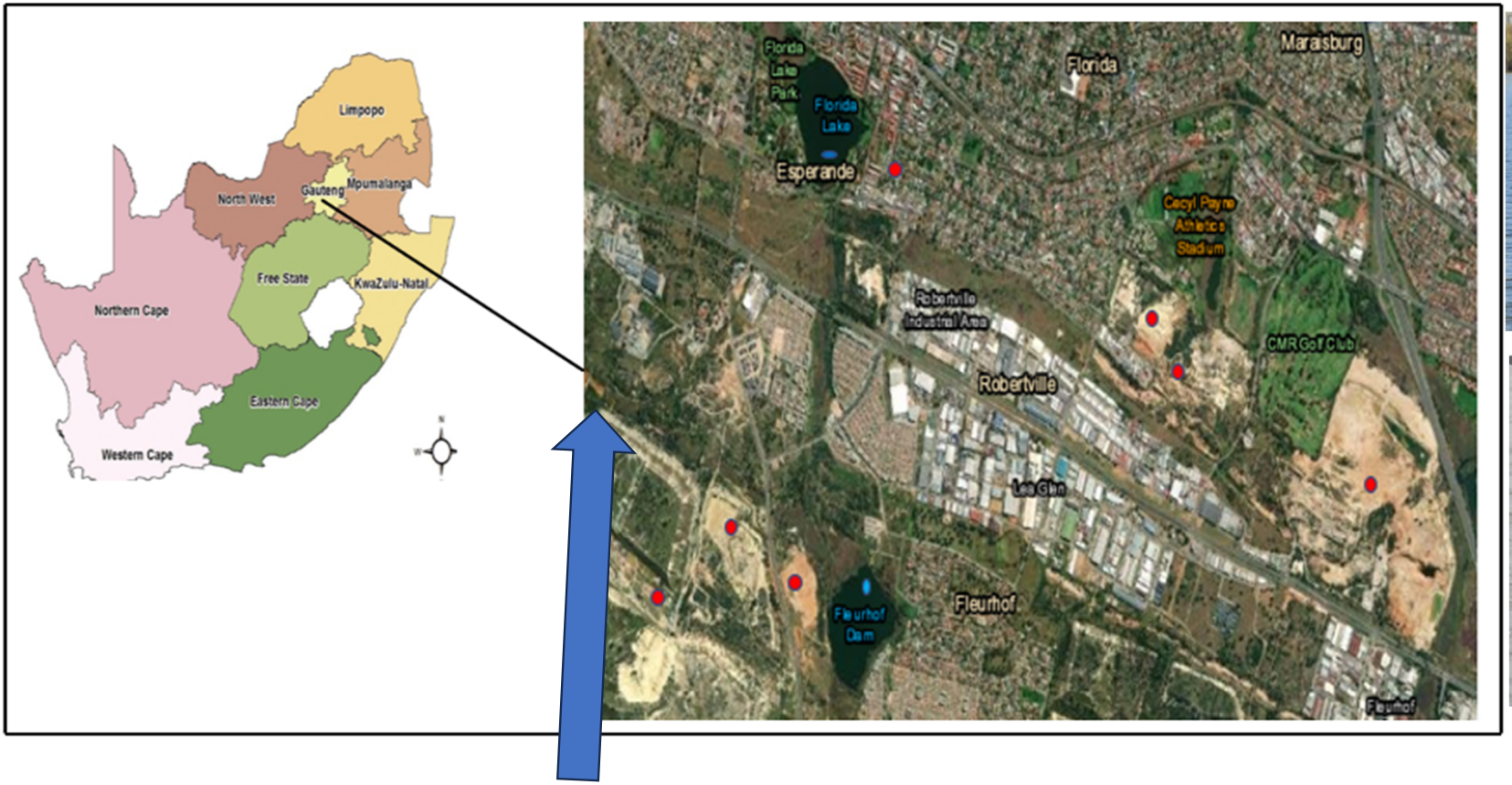
- Cancer
- Organs failure
- Brain damage
- Birth defects

Study area

Johannesburg, Gauteng province, South Africa.

Surface waterbodies

Mine dumps



- The Marie-Louise landfill site which is surrounded by gold mine dumps

This study is **aimed** at evaluating the movement of Cd^{2+} and Pb^{2+} from landfill and mine dump sites to waterbodies.

Objectives

- Ascertain contaminants and develop a predictive model based on the analytical data
- Establishing the distribution and behaviour of the contaminants through speciation and reaction transport models
- Determine the safety of groundwater and surface water in the vicinity of landfill and mine dump sites.

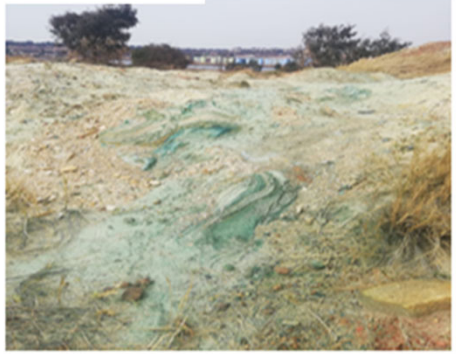
Methodology

Mine dump site A

Mine dump site B

Mine dump site C

Mine dump site D



Solid samples collected from mine dump and landfill sites

0.5 g of the solid samples were added to 6 mL HNO_3, 3 mL HF, 3 mL H_2O_2 and 2 mL HCl

Digested using a microwave

Analyzed with inductively coupled plasma optical emission spectroscopy (ICP-OES)

Liquid samples from the Fleurhof dam, Florida Lake, and ponds around the study area were also collected

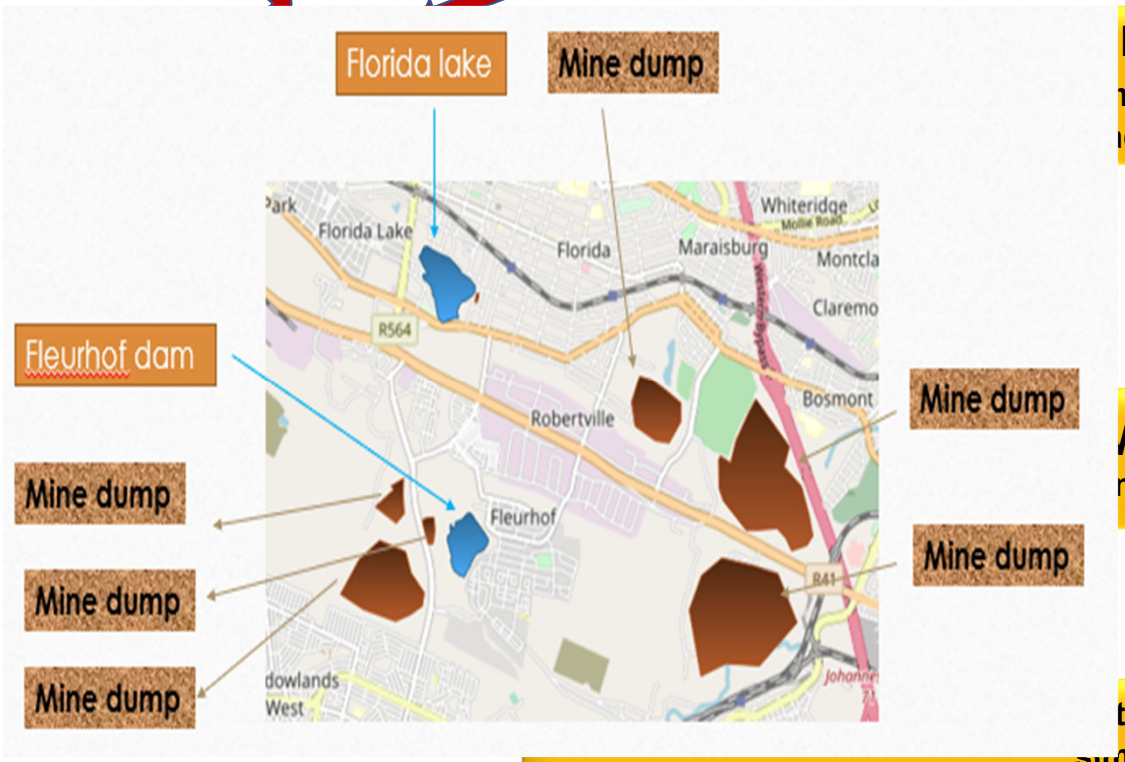
The samples were centrifuged and filtered

Stepwise adopted methodology for the model set-up

Represent the geographical features of the study area in QGIS

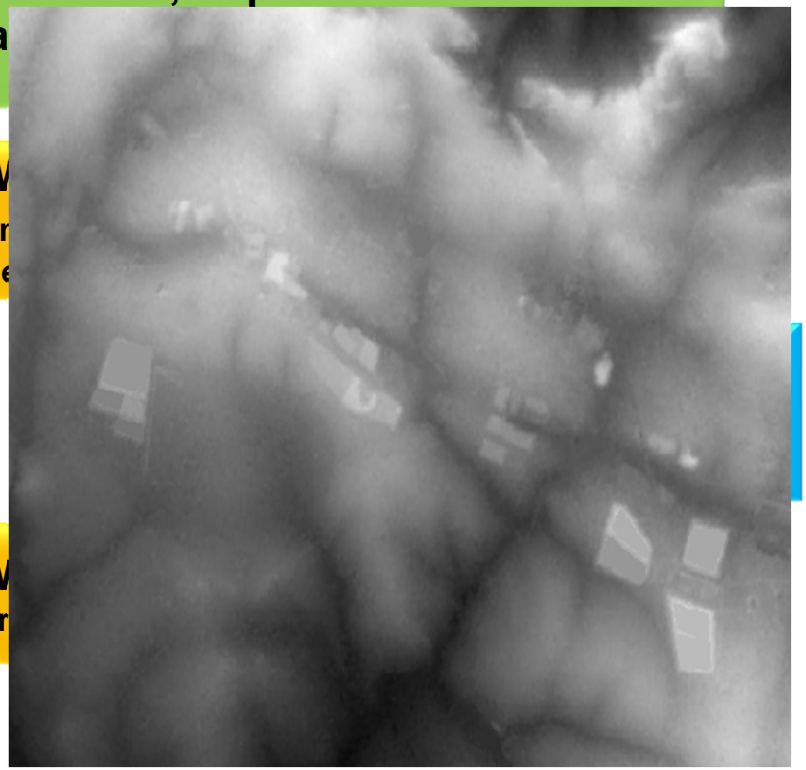
Import the DEM from Earth explorer into QGIS

Obtain geological and hydrological data from literature, Department of Water and Sanita



MODFLOW
mensional Fir
dwater mode

MODFLOW
mulation for r

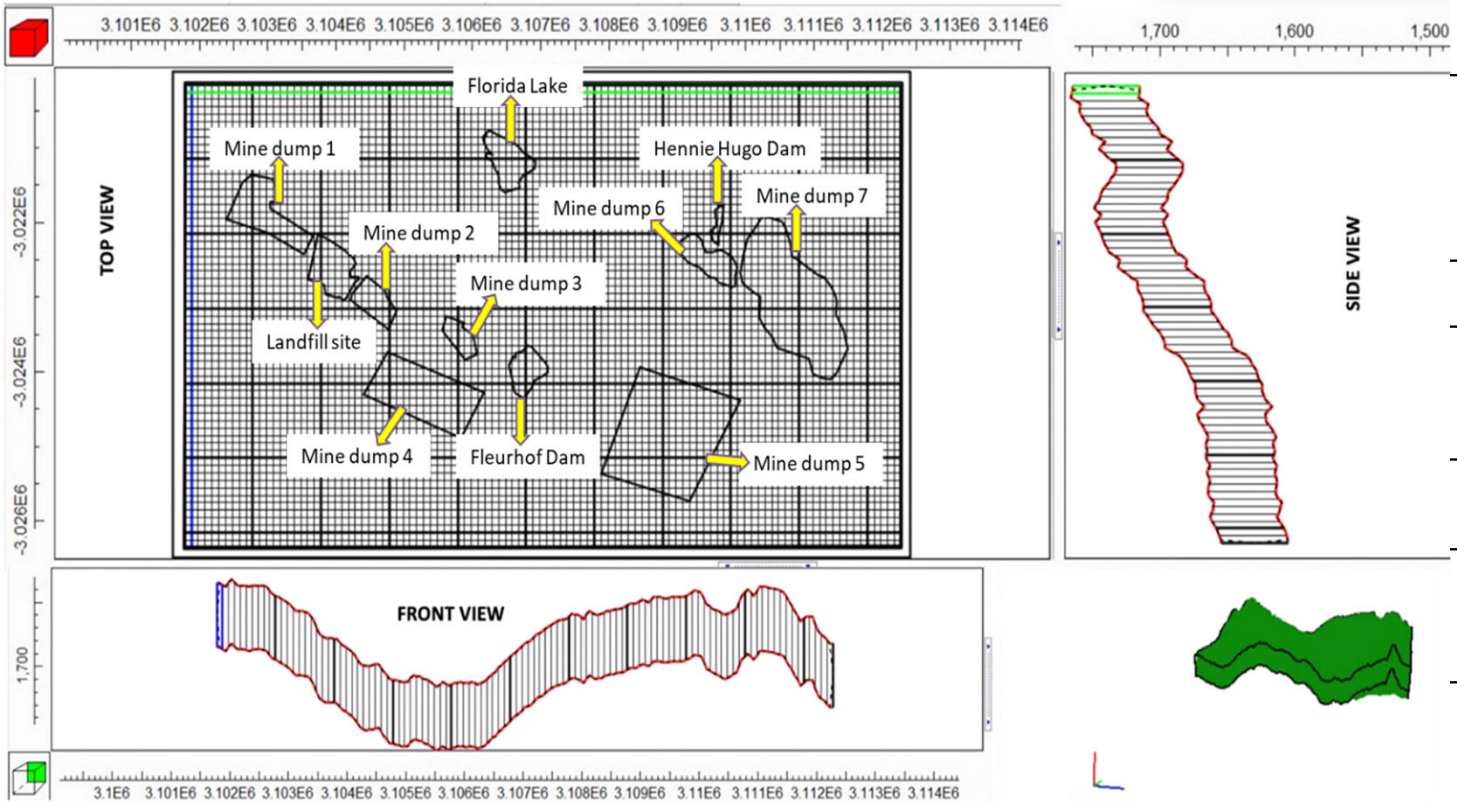


three-dimensional transport model for simulation)
-To study the transport and dispersion of the pollutants

Methodology

The migration of Pb^{2+} and Cd^{2+} from the landfill and mine dumps to groundwater and surface waterbodies was simulated using MODFLOW numerical modelling.

MODFLOW 2005 computer code was used to develop a numerical representation of the hydrogeologic environment of the study site.

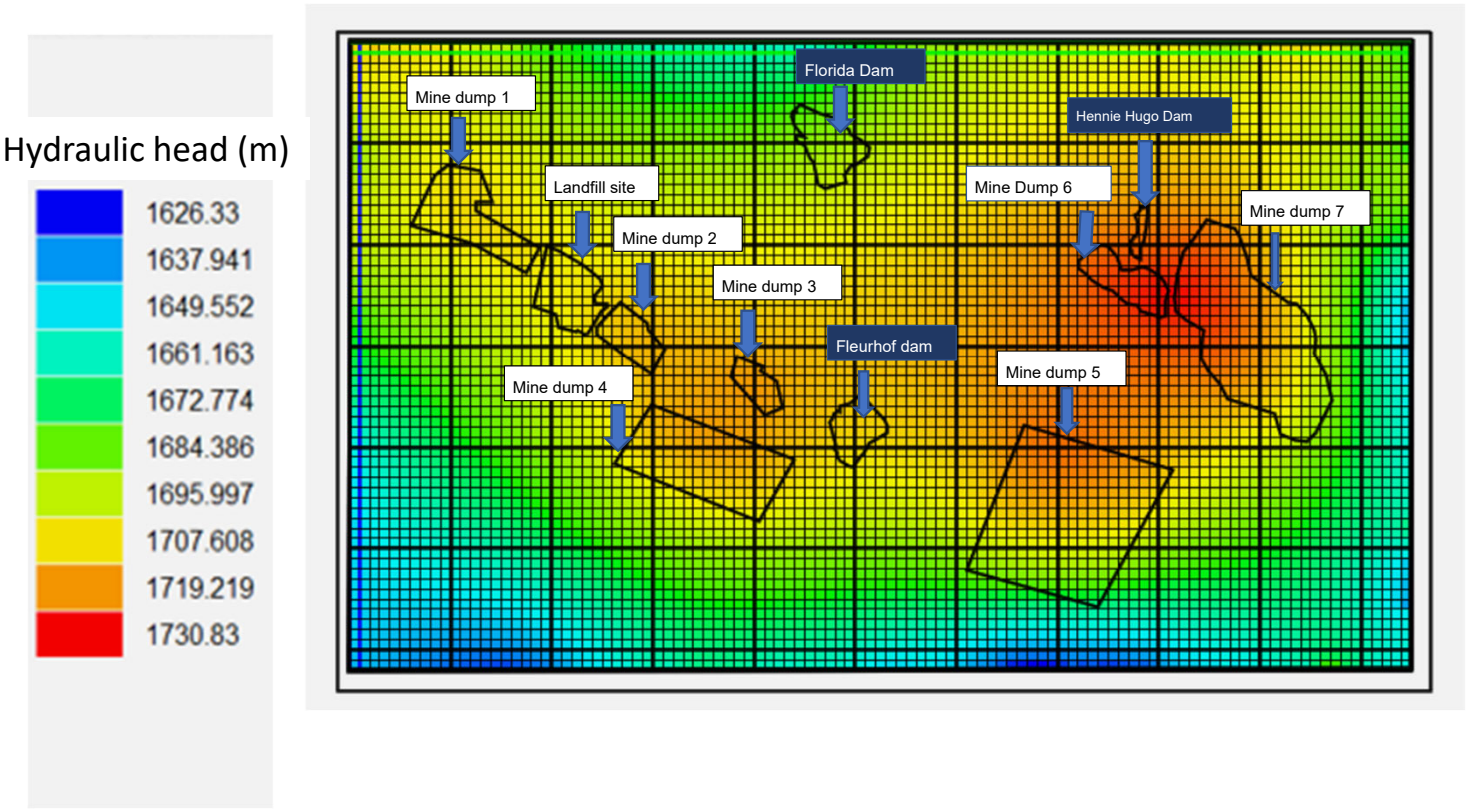


Hydraulic Conductivity (mS cm $^{-1}$)	Recharge rate (m/s/year)	Depth to groundwater (m)
8 mS cm $^{-1}$	2.486×10^{-8}	17

Lithology	Thickness (m)	Porosity
Quartzite	60	0.22
Conglomerate	15	0.188

Results

Hydraulic heads of the study area



The concentrations of the elements from the mining dump sites and landfills.

Different dissolved elements including Fe^{2+}, K^{+}, SO_4^{2-}, Cl^{-}, NO_3^{-}, Mg^{2+}, Mn^{2+}, Zn^{2+}, Cu^{2+} and Na^{+} were detected in mine dumps and landfill site.

Element	Dump site 1	Dump site 2	Dump site 3	Dump site 4	Dump site 5	Landfill	Permissible limits in drinking water (WHO)
Arsenic (mg/L)	3.10	2.15	5.03	0.52	1.18	2.87	0.01
Chromium (mg/L)	11.64	5.59	7.14	2.11	7.42	3.5	0.05
Uranium (mg/L)	0.728	0.7	0.98	0.27	1.12	0.98	0.015
Cadmium (mg/L)	0.28	1.21	0.66	0.24	0.52	1.24	0.003
Lead (mg/L)	0.44	2.11	0.32	0.03	0.12	0.62	0.01

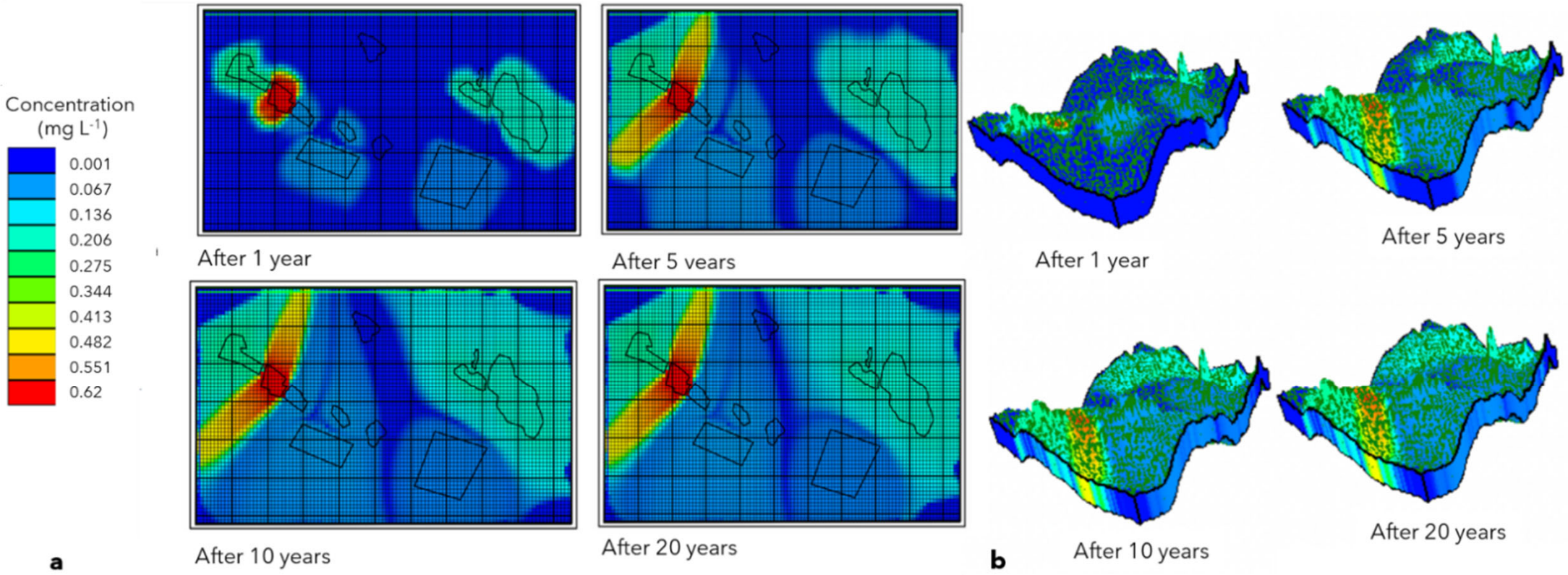
The speciation of the elements in waterbodies and the landfill leachate was determined using PHREEQC geochemical code. To do this, conditions such as pH, concentration of cations and anions, pe, temperature, density and redox were specified.

- These elements are usually found in trace concentrations in aquatic environments and pose a great concern to human health

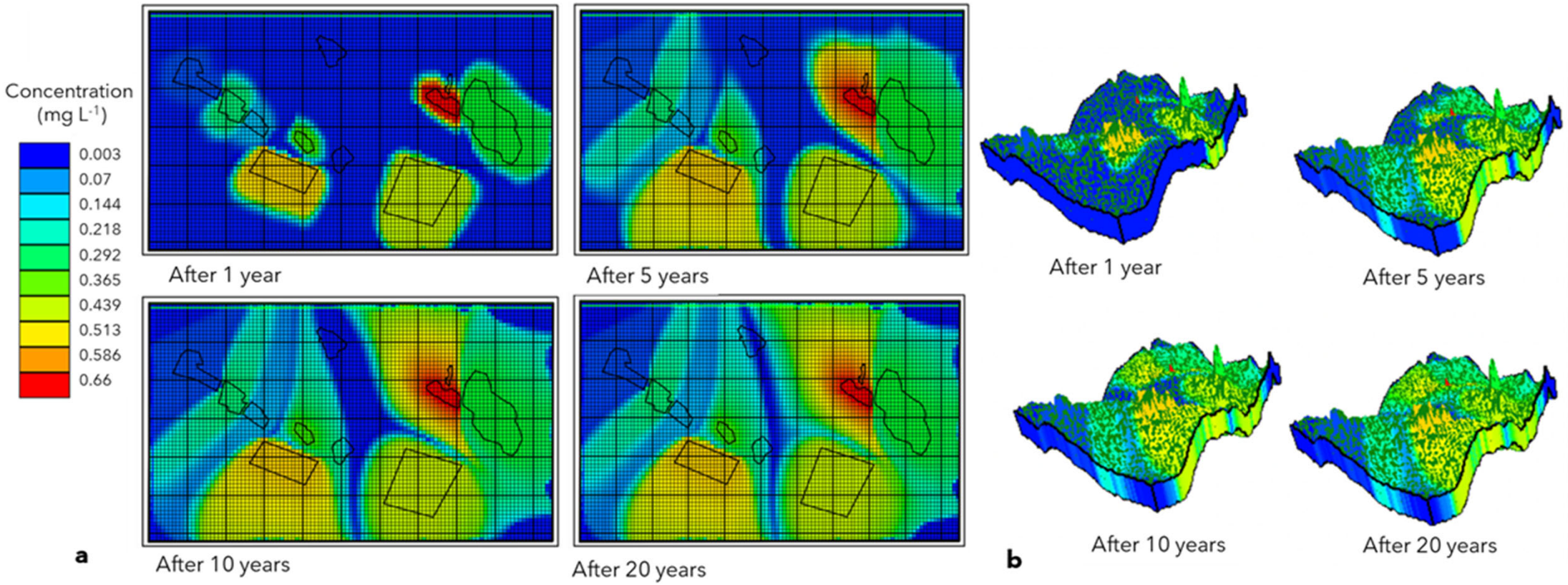
- Some areas rely on borehole water which has not undergone any form of treatment
- Drinking
- Domestic purposes (e.g. washing and bathing)
- Agriculture

Results

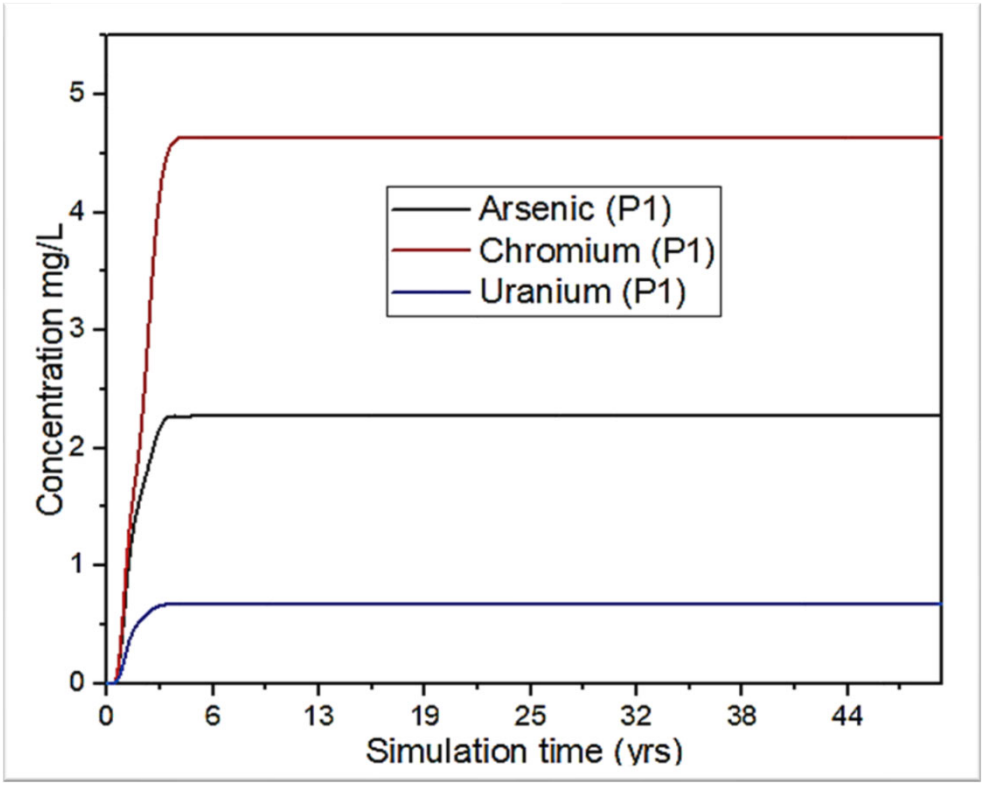
The (a) horizontal and (b) vertical transport of Cd^{2+} in the study area

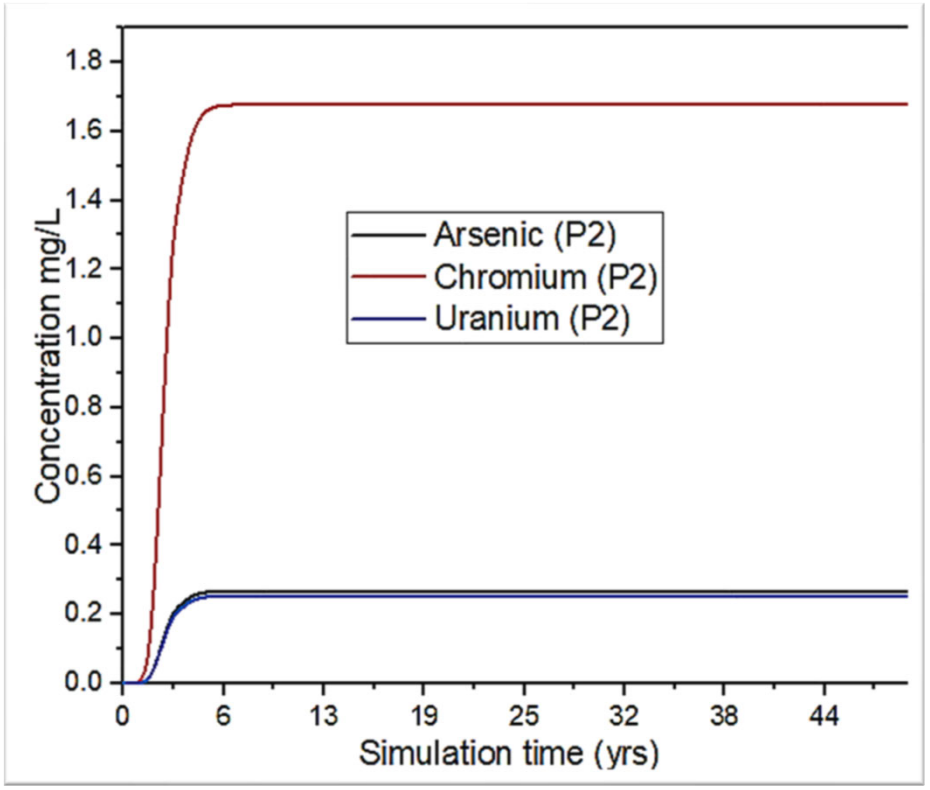


The (a) horizontal and (b) vertical transport of Pb^{2+} in the study area

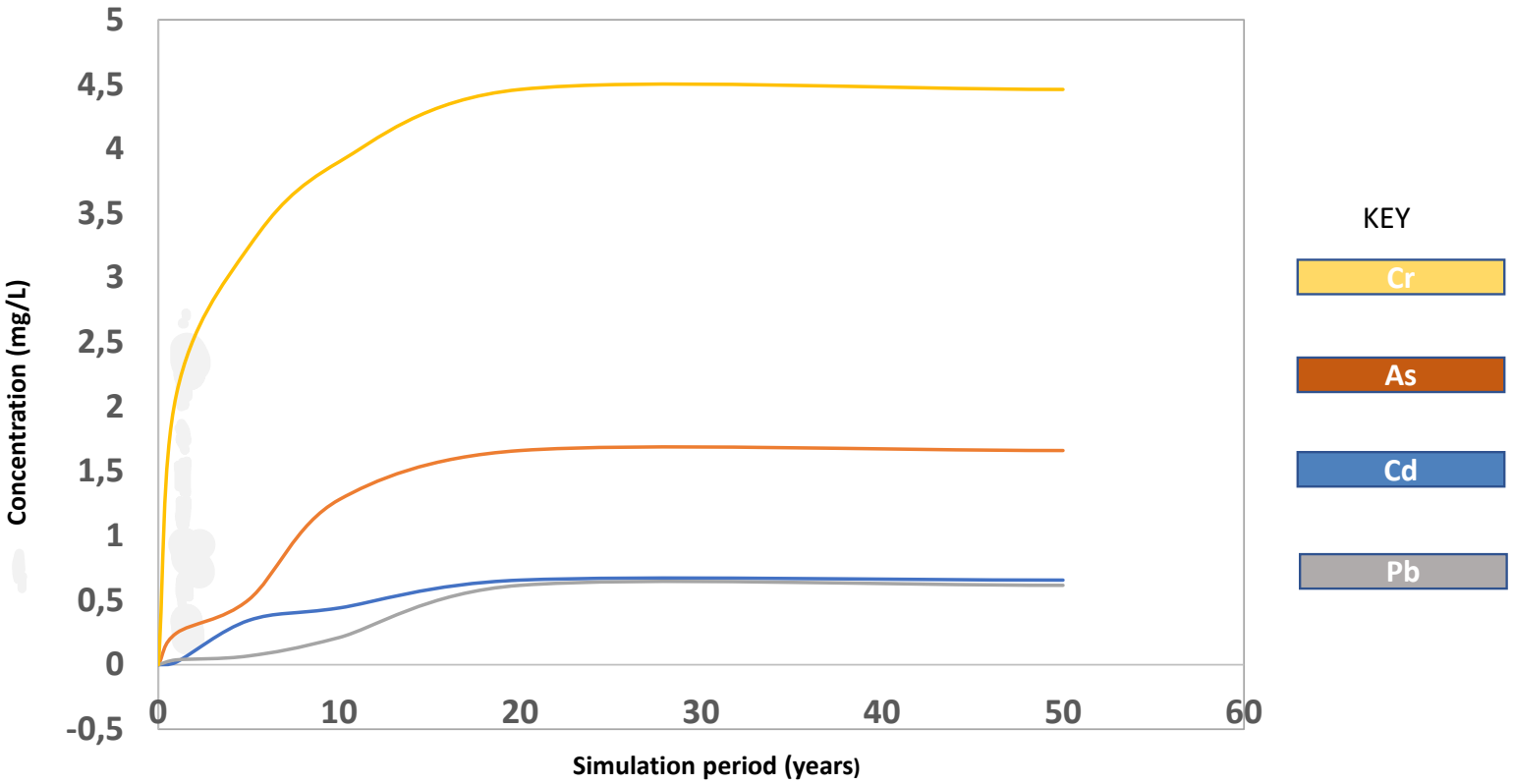


Pollutant concentrations at observation point P1 (Fleurhof Dam) and P2 (Florida Lake).





Pollutant concentration in waterbodies with respect to time



Conclusions

Waterbodies in the vicinity of the Marie-Louise landfill site and mine dumps were contaminated by toxic elements (incl. Pb^{2+} and Cd^{2+}) which can travel to waterbodies in the study area,
- leading to concentrations which are above the threshold limits as set by the World Health Organisation (WHO).

The modelling results indicated that the transport of elements will continue if not prevented.

This means that local residents depending on the waterbodies for different purposes are prone to negative side effects as a result of the high concentrations of elements, some of which are toxic in very low concentrations.

Other elements such as Fe^{2+}, K^{+}, SO_4^{2-}, Cl^{-}, NO_3^{-}, Mg^{2+}, Mn^{2+}, Zn^{2+}, Cu^{2+} and Na^{+} were also found to be in high concentrations in the waterbodies as a result of the mine dumps.

MODFLOW-MT3DMS can be used to simulate the transport of contaminants from their sources. This is important for determining the role of mine dumps and landfill sites on the environment.

Moreover, future prediction of the level of transport of the contaminants using MODFLOW-MT3DMS will help with identifying areas that require urgent remediation strategies.

Future studies

- FEFLOW
- back-track the simulation
- Consider the effect of the reduced porosity
- Determine the rate of transport of pollutants in different seasons

Acknowledgements

Prof. Hlanganani Tutu

Prof. Patrick Ndungu

WITS UNIVERSITY

ENVIRONMENTAL ANALYTICAL chemistry
School of Chemistry
University of the Witwatersrand

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

water & sanitation
Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

NRF National Research Foundation

WVTF IMWA 2024
West Virginia Mine Drainage Task Force Symposium &
15th International Mine Water Association Congress
April 21–26, 2024 | Morgantown, WV, USA

References

Aloke, C., Uzuegbu, I. E., Ogbu, P. N., Ugwuja, E. I., Orinya, O. F., & Obasi, I. O. (2019). Comparative assessment of heavy metals in drinking water sources from Enyigba Community in Abakaliki Local Government Area, Ebonyi State, Nigeria. *African Journal of Environmental Science and Technology*, *13*(4), 149-154.

Brunner, P., Simmons, C. T., Cook, P. G., & Therrien, R. (2010). Modeling surface water-groundwater interaction with MODFLOW: Some considerations. *Groundwater*, *48*(2), 174-180.

Chowdhury, A., & Rahnuma, M. (2023). Groundwater contaminant transport modeling using MODFLOW and MT3DMS: a case study in Rajshahi City. Water Practice and Technology, 18(5), 1255-1272.

Ebrahimi, M., Khalili, N., Razi, S., Keshavarz-Fathi, M., Khalili, N., & Rezaei, N. (2020). Effects of lead and cadmium on the immune system and cancer progression. *Journal of Environmental Health Science and Engineering*, *18*, 335-343.

Harrison, P., & Zack, T. (2012). The power of mining: the fall of gold and rise of Johannesburg. *Journal of contemporary African studies*, *30*(4), 551-570.

Hussein, M., Yoneda, K., Mohd-Zaki, Z., Amir, A., & Othman, N. (2021). Heavy metals in leachate, impacted soils and natural soils of different landfills in Malaysia: An alarming threat. *Chemosphere*, *267*, 128874.

Huang, J., Yuan, F., Zeng, G., Li, X., Gu, Y., Shi, L., ... & Shi, Y. (2017). Influence of pH on heavy metal speciation and removal from wastewater using micellar-enhanced ultrafiltration. Chemosphere, 173, 199-206.

Mohlala, T. (2006), Dumping ground, Mail and Guardian, https://mg.co.za/article/2006-06-13-dumping-ground/ [Accessed: 19 December 2023]

Naicker, K., Cukrowska, E., & McCarthy, T. S. (2003). Acid mine drainage arising from gold mining activity in Johannesburg, South Africa and environs. Environmental pollution, 122(1), 29-40.

Sibiya, I. V., Olukunle, O. I., & Okonkwo, O. J. (2017). Seasonal variations and the influence of geomembrane liners on the levels of PBDEs in landfill leachates, sediment and groundwater in Gauteng Province, South Africa. *Emerging Contaminants*, *3*(2), 76-84.

Talalaj, I. A. (2014). Assessment of groundwater quality near the landfill site using the modified water quality index. *Environmental monitoring and assessment*, *186*, 3673-3683.

Turton, A. (2015). When gold mining ends: An environmental catastrophe for Johannesburg. *New South African Review 5: Beyond Marikana*, 120-142.

Vareda, J. P., Valente, A. J., & Durães, L. (2019). Assessment of heavy metal pollution from anthropogenic activities and remediation strategies: A review. *Journal of environmental management*, *246*, 101-118.

Vaverková, M. D. (2019). Landfill impacts on the environment. *Geosciences*, *9*(10), 431.

Thank you

Ke a leboga