Assessing heavy elements in tailings water around a Uranium mine in Namibia

Vera Uushona[1,2], Manny Mathuthu[1]

[1]*Center for Applied Radiation Science and Technology (CARST), North-West University (Mafikeng), Cnr Albert Luthuli Road and University Drive, 2735, Mmabatho, South Africa, nvuushona@yahoo.com, Manny.Mathuthu@nwu.ac.za*

[2]*National Radiation Protection Authority of Namibia, Ministry of Health and Social Services, Harvey Street, Namibia*

Abstract

The study investigated the concentration of heavy elements in ground water and process water from the tailings of a uranium mine in Namibia. Inductively Coupled Plasma Mass Spectrometry was used to evaluate the concentration of heavy metals. Tailings water had higher average concentration of elements compared to ground water. The concentration of uranium in the ground water was above 15 µgl-1 and 30 µgl-1 as set by WHO and USEPA This shows that the ground water near the uranium mine is toxicologically not fit for human consumption.

Keywords: Uranium Mine, Tailings Water, Ground Water, Heavy Elements, ICP-MS

Introduction

IMWA2021 Mining and processing of minerals is a key economic activities that contributes to the growth and development of economies of nations. At the same time, mining also produces huge amount of waste that contributes to environmental contamination to the nearby communities by releasing heavy elements to the air, soil and water both surface and ground water (Sracek *et al*., 2012, Olawuyi and Mudashir, 2013, Madzunya *et al*., 2020).

Heavy elements are present in the environment and some are vital for living organisms including human but can be toxic at higher concentrations (Singh *et al*., 2011). Heavy elements are not broken down and thus transferred to humans through food, water, soil or air. The toxicity of the metals is depended on the type of metal, the dose taken and whether the exposure was chronic or acute (CSIR, 2008). Heavy elements such uranium, potassium, strontium, chromium, Manganese and Thorium are geochemically classified as lithophilic metals, while Zinc metal and Arsenic share the Chalcophile/ Lithopilic nature which is signified by their bioaccumulation in the human tissue thus becoming chemo-toxic.

A major concern of mining is acid drainage, that occurs when acids such as sulphuric are added during the mining process and has potential to may pose a long-term devastating impact on rivers, streams and aquatic life. These acids/toxic chemicals are carried through to the tailings dam. When the tailings fail, the seepage can end up in the ground water systems/aquifer to communities in the downstream (Kamunda *et al*., 2016).

The study aimed to measure the concentration levels of heavy elements in tailings process water and ground water. In this study, eight heavy elements, namely Sr, K, U, Mn, Zn, As, Cr and Th were included in the measurement.

Methods

The Study Area

The study area is the Erongo region, situated in Western part of Namibia, arid Namib desert. It lies between -23° 06' 60.00" S latitude and: 14° 51' 59.99" E longitude. The region is rich in various mineralisation such as Gold, Uranium and Lead. Uranium mineralisation was discovered in 1928 (MME, 2010) (MME, 2010). Due to confidentiality agreements signed, the exact location where samples were collected cannot be disclosed. See Figure 1.

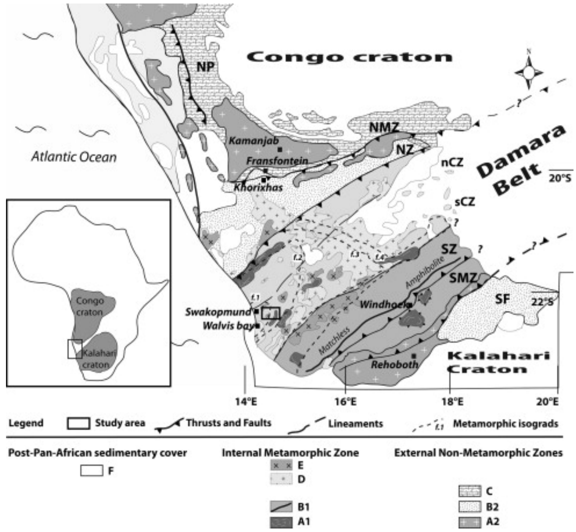

Figure 1 *Location of the Damara orogenic belt between the Congo and Kalahari cratons (Toé et al., 2013).*

Sample collection, preparation and analyses

Twenty samples were collected, 10 ground water and 10 process water from the tailings. The samples were collected in one-litre polyethylene water bottles. The bottles were rinsed with distilled water prior to filling. The samples were treated with 1% Nitric acid. The samples were transported to the Analytical Laboratory at the Centre for Applied Radiation Science and Technology (CARST) for analysis

At the laboratory water samples were filtered utilizing a Whatman No. 41 filter paper to remove any particles. 5 mL of the sample was mixed with 1 mL of 70% of HNO_3 and deionized water was added to fill up to the 10 mL.

The concentrations of uranium and heavy elements were analysed using an Inductively Coupled Plasma Mass Spectrometer (ICP-MS) PerkinElmer NexION 2000, total quant method. The multi-element standard by Perkin Elmer with a concentration of 10 mg/L and elements: Ag, Al, As, Ba, Be, Bi, Ca, Cd, Co, Cr, Cs, Cu, Fe, Ga, In, K, Li, Mg, Mn, Na, Ni, Pb, Rb, Se, Sr, Tl, U, V and Zn was used for calibrating the ICP-MS. The analysis was replicated three times. To check for contamination and drift, the instrument was set to measure blank solution and calibration standard at every 10 set of measurements (Kamunda *et al*., 2016, Madzunya *et al*., 2020). All the chemicals and reagents used were of certified analytical grade and procured from Merck (South Africa).

Results and Discussions

A total of 20 samples analysed for elemental concentration using ICP-MS. The concentrations of heavy metals ground and tailings water (µgL-1) are presented in Tables 1 and 2 respectively.

The average concentrations of heavy elements in the ground water decreased in the order of Sr>K>U>Mn>Zn>As>Cr>Pb>Th. The ranges in µgL-1 were as follow: Sr (2657.06-3216.08), U (121.77-221.26), Zn (6.24-101.02), Mn (29.03-142.46), As (6.43-8.35), Cr (5.26-10.11), Pb (3.35-9.10), Th (0.54-3.98) and K (16916.89-20694.52), respectively. Similarly, the average concentrations of heavy metal in the tailings water decreased in the order of U>Sr>Cr>As>Th. The ranges in µgL-1 were as follow: Sr (8.48-43.66), U (145682.13-239254.77), As (3159.30), Cr (38.27-59.28) and Th (12.40-19.28) respectively.

The results show that mine tailings had generally higher concentrations of of Sr, Cr, U and Th compared to ground water. This may have been caused by acid mine drainage that dissolves heavy metals into the ground

Table 1 Average elemental concentration of heavy metals (μgL-1) in ground water.

	Elemental concentration of heavy metals (μgL^{-1})								
Sample no	**Sr**	**U**	**Zn**	**Mn**	**As**	**Cr**	**Pb**	**Th**	**K**
1	2978.29	134.05	6.5	40.84	6.86	5.34	3.58	1.60	19216.44
2	3013.07	159.66	8.52	40.2	7.18	5.26	4.04	0.63	19436.21
3	3216.08	221.26	17.1	57.2	8.35	6.01	5.58	1.39	20694.52
4	3029.2	197.66	13.52	121.95	7.35	10.11	7.73	3.98	19900.11
5	2657.06	126.5	101.02	56.42	6.64	6.63	3.64	0.54	16916.89
6	2834.3	160.18	39.29	142.46	7.04	7.36	9.1	1.22	18844.53
7	2913.95	137.97	6.24	51.12	7.4	9.06	3.86	1.54	19057.2
8	2898.8	174.19	6.66	86.71	7.16	7.46	7.18	3.39	19028.55
9	2673.32	167.94	8.41	87.96	6.43	5.52	5.59	2.72	16953.45
10	2728.63	121.77	28.74	29.03	6.85	6.24	3.35	1.54	17742.57
Average	**2894.27**	**160.12**	**23.60**	**71.39**	**7.13**	**6.90**	**5.37**	**1.86**	**18779.05**
STDEV	**176.22**	**31.93**	**29.34**	**37.50**	**0.53**	**1.63**	**2.03**	**1.14**	**1227.81**
min	**2657.06**	**121.77**	**6.24**	**29.03**	**6.43**	**5.26**	**3.35**	**0.54**	**16916.89**
max	**3216.08**	**221.26**	**101.02**	**142.46**	**8.35**	**10.11**	**9.10**	**3.98**	**20694.52**

Table 2 The average elemental concentration of heavy metals (μgL-1) in tailings process water.

	Elemental Concentration (μgl^{-1})				
Sample No	**Sr**	**U**	**As**	**Cr**	**Th**
1	8.48	145682.13	3159.3	38.46	12.4
2	12.55	155069.06	3229.62	41.1	13.28
3	29.18	186777.79	3579.92	38.27	15.22
4	36.85	200893.93	4056.96	49.2	16.58
5	40.6	214212.05	4145.88	45.77	17.38
6	40.05	220455.95	4153.35	48.54	17.96
7	41.34	226964.59	4185.37	59.28	18.62
8	42.54	231980.74	3998.59	43.34	18.78
9	43.66	235766.00	3978.21	47.47	19.28
10	41.52	239254.77	3960.11	49.93	19.25
Average	33.68	205705.70	3844.73	46.14	16.88
STDEV	12.90	33349.54	382.99	6.31	2.48
min	8.48	145682.13	3159.30	38.27	12.40
max	43.66	239254.77	4185.37	59.28	19.28

(Madzunya *et al.*, 2020). As heavy metals concentrations in drinking water collected from Municipality water treatment plant did not exceed the stipulated limits by USEPA and DWAF and is toxicologically safe for the members of the public (Madzunya et al., 2020).

The concentration of uranium in the ground water was above 15 μgl-1 and 30 μgl-1 as set by World Health Organization (WHO) and Unites States Environmental Protection Agency (USEPA) (WHO, 2004, USEPA, 2011), this is attributed to the fact the ground water is in a uranium rich province. Hence, based on the elemental concentration of U, the ground water from the study is not fit for human consumption as it exceeds the recommended limits. Equally, the water from tailings, if they mix with the ground water bodies, can cause significant toxicological to the ground water bodies

Conclusions

The study investigated the concentration of heavy metals in the ground and tailings water from uranium mine. The study concludes that the ground water around the uranium mine is toxicologically not safe for public drinking. The mine operators should ensure that adequate measures are in place to avoid seepage of tailing water into the ground water aquiver of the Erongo region. This can be achieved by ensuring that seepage control mechanism is effectively in place.

Acknowledgements

The authors thank the Technical student (Ms Naomi Dikeledi Mokhine) at the Centre for Applied Radiation Science and Technology, NWU, for assistance in all Analytical Laboratory analysis of samples

References

CSIR 2008. High Confidence Study of Children Potentially Affected by Radionuclide and Heavy Metal Contamination Arising from the Legacy of Mine Water Management Practices on the Far West Rand of South Africa, Project Concept Note. Council for Scientific and Industrial Research. Pretoria.

Kamunda, C., Mathuthu, M. & Madhuku, M. 2016. Health Risk Assessment of Heavy Metals in Soils from Witwatersrand Gold Mining Basin, South Africa. *Int J Environ Res Public Health*, 13.

Madzunya, D., Dudu, V. P., Mathuthu, M. & Manjoro, M. 2020. Radiological health risk assessment of drinking water and soil dust from Gauteng and North West Provinces, in South Africa. *Heliyon*, 6, e03392.

MME 2010. Strategic Environmental Assessment for the central Namib Uranium Rush. Windhoek, Namibia: Ministry of Mine and Energy.

Olawuyi, A. & Mudashir, R. 2013. Environmental and health impact of mining in Abara and Tungar Community of Anka Local Governement Area of Zamfara State, Nigeria. *Congress of Geological Society of Africa*. Addis Ababa, Ethiopia.

Singh, R., Gautam, N., Mishra, A. & Gupta, R. 2011. Heavy metals and living systems: An overview. *Indian journal of pharmacology*, 43, 246-253.

Sracek, O., Kříbek, B., Mihaljevič, M., Majer, V., Veselovský, F., Vencelides, Z. & Nyambe, I. 2012. Mining-related contamination of surface water and sediments of the Kafue River drainage system in the Copperbelt district, Zambia: An example of a high neutralization capacity system. *Journal of Geochemical Exploration*, 112, 174-188.

Toé, W., Vanderhaeghe, O., André-Mayer, A. S., Feybesse, J. L. & Milési, J. P. 2013. From migmatites to granites in the Pan-African Damara orogenic belt, Namibia. *Journal of African Earth Sciences*, 85, 62-74.

USEPA 2011. National Primary Drinking Water Regulations.

WHO 2004. Guideliness for Drinking Water Quality. Geneva: World Health Organization.