

ABSTRACT

Mercury (Hg) pollution is especially prominent in areas of active and closed mining sites. In dry areas, mine tailings are important sources of pollution because highly contaminated particles can be dispersed by water and wind. Once present in a given environment, Hg has the potential of being transformed into forms that will affect its properties and fate. In this study, the BCR sequential extraction procedure (SEP) was used to characterise Hg fractionation in soils and tailings in the mining towns of Berg Aukas and Tsumeb in northern Namibia. The BCR SEP separates metals into four fractions, namely: exchangeable (F1), reducible (F2), oxidisable (F3) and residual (F4).

Keywords: Mercury, Sequential extraction, fractionation, Berg Aukas, Tsumeb

INTRODUCTION AND OBJECTIVES

Berg Aukas (Fig.1) is an abandoned a mine where they used to roast Pb, V & Zn ores between 1913 – 1979 and it is known to be polluted with heavy metals. The mining town of Tsumeb (Fig.1) was founded in 1899 and is famous for its rich mineral ore deposits (e.g. Cu, Pb). Anthropogenic sources, especially mining activities, are known to contribute significantly to the release of heavy metals found at contaminated sites. One of the commonly studied heavy metals is Hg, due to its toxic and volatile nature. Hg is a naturally occurring metal that exists in three different forms of variable properties namely: Elemental (Hg⁰), inorganic (Hg₂²⁺ & Hg²⁺) and organic (R-HgX). To understand the behaviour and ecosystem fate of Hg in areas impacted by mining activities, it is critical to study its speciation.

Hence, this research aimed at characterising the different forms of occurrence of Hg and describing its distribution in tailings, soils, waters and plants from mining impacted areas in Berg Aukas and Tsumeb.

The Occurrence and Distribution of Mercury in Selected Namibian Areas Affected by Mining Activities

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RESULTS AND DISCUSSION

1. Total Hg content (HgT)

HgT results revealed high levels in tailings (up to 2.24 mg/kg, Fig. 3) and soils (up to 3.49 mg/kg, Fig. 4). Hg levels in soils were generally beyond guidelines threshold levels with very high to extremely high enrichment. Water samples from Berg Aukas had higher Hg values than the maximum allowed for drinking water (up to 6 µg/L, Fig. 5). Some plants collected at Berg Aukas also had high Hg levels reaching a maximum of 0.70 mg/kg (Fig. 5). Most of the plants from wetland in Berg Aukas had a soil-plant transfer coefficient (TC) higher than 0.1 indicating the bioavailability of Hg in the soil. These findings suggest that the main source of Hg pollution in Berg Aukas is the poorly maintained tailing dumps found in the area which release Hg mainly through runoff as well as through wind dispersion of Hg-bearing tailings particles and that past roasting operations in Berg Aukas could be the principal cause of Hg deposition in the proximity of the old smelter.

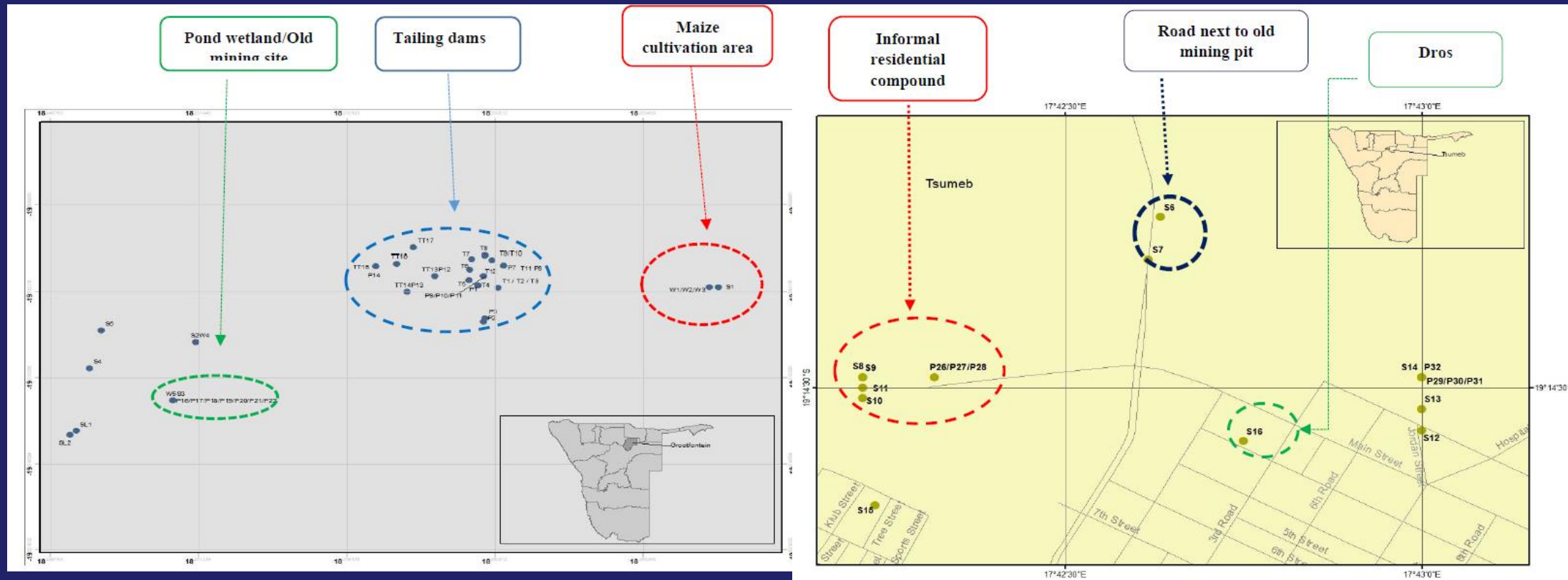


Figure 1. Sampling areas in Berg Aukas (left) and Tsumeb (right)

MATERIALS & METHODS

Soils, tailings, waters and plants were collected at the study sites. Ancillary data such as pH, EC, ORP were measured on site and later used for correlation analysis. IC was used for the analysis of anions. The different forms of Hg association were determined by means of BCR SEP using appropriate solvents (Table 1). Hg analysis was carried out with a DMA-80 (Milestone) as shown in Fig.2 . The BCR method was validated using the CRM BCR-701 of lake sediment.

Extraction step	Reactive / concentration / pH	Solid phase/Fraction
F1	CH ₃ COOH (0.11 M), pH 2.85	Exchangeable, water/acid soluble (e.g., HgCl ₂ ; Hg(OH) ₂)
F2	NH ₂ OH-HCl (0.1 M) pH 2	Reducible (e.g., Hg ⁰ ; HgSO ₄)
F3	H ₂ O ₂ (8.8 M), CH ₃ COONH ₄ (1.0 M) pH 2	Oxidisable (e.g., R-Hg-X; Hg-S)
F4	3HCl + HNO ₃	Residual (Hg ⁰ ; Hg-S; Silicate bound metals)

Table 1. The BCR SEP and plausible Hg fractions



Figure 2. The DMA-80 Milestone

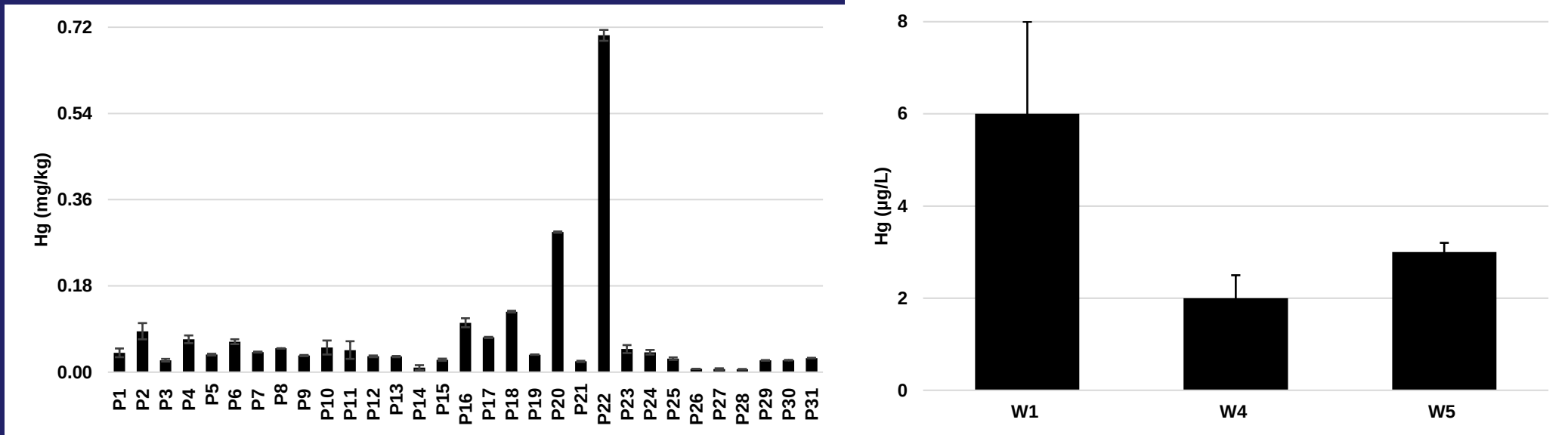


Fig 5. HgT in Plants (left) and Waters (right)

2. SEP analysis

Distribution of Hg in tailings revealed about 8% to be exchangeable (F1) and almost 92% of Hg was residual, F4 (Fig. 6). Potential Hg species that can be found in F4 are HgS, Hg⁰ and HgSe. F4 in tailings correlated with S²⁻ (r = 0.708) and could be an evidence of the presence of sulphide bound Hg phase minerals (e.g. cinnabar). In contrast, the exchangeable Hg fraction (F1) in Berg Aukas soils was as high as 35% of HgT (Fig. 7). This fraction may explain the Hg uptake in wetland plants (P20 - P22 in Fig. 5) and is a reason for concern due to the risks of Hg methylation. The high F2 observed in S4 and S5 (Mean: 78%) could be the combination of Hg bound to Mn and Fe oxides together with the Hg complexed to humic substances, HgOH and HgClOH species. Sample S3 from Berg Aukas wetland was the only one with 100% residual (non-labile) Hg indicating that all labile forms of Hg have dissolved in the water.

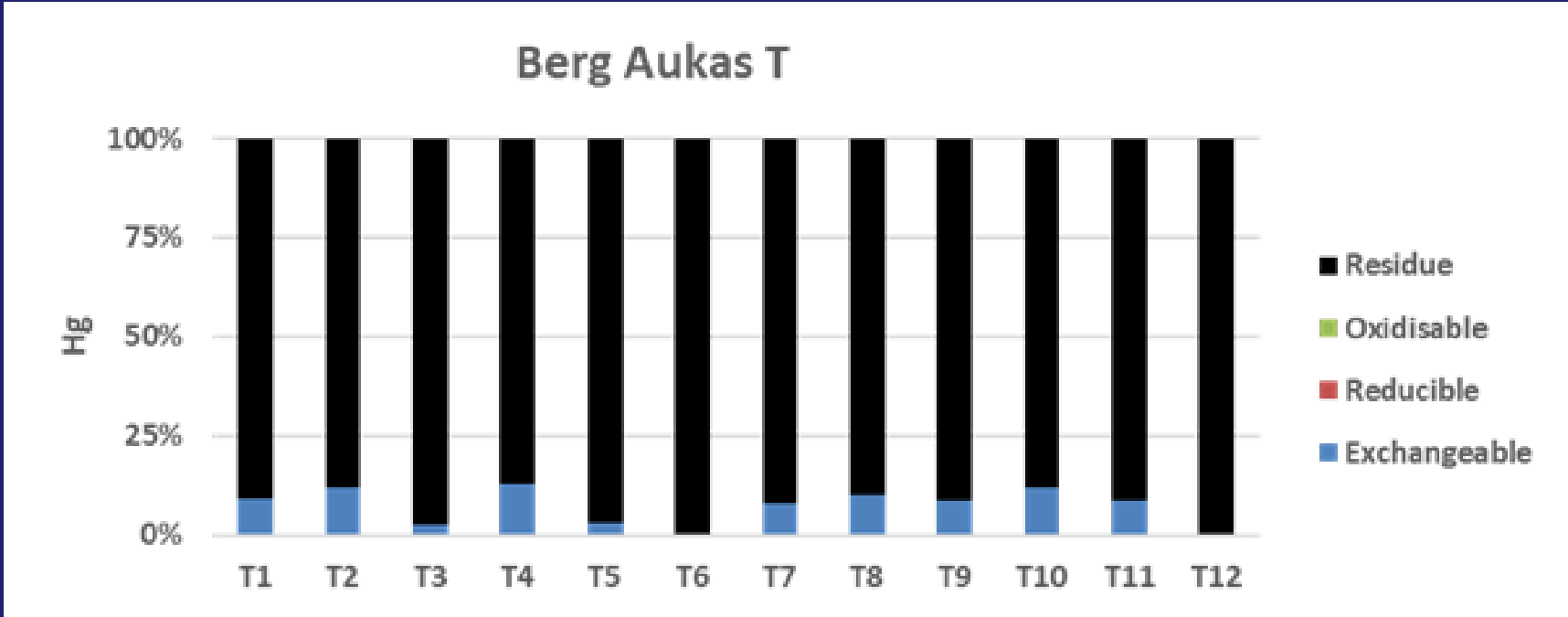


Fig 6. Speciation of Hg in Berg Aukas tailings

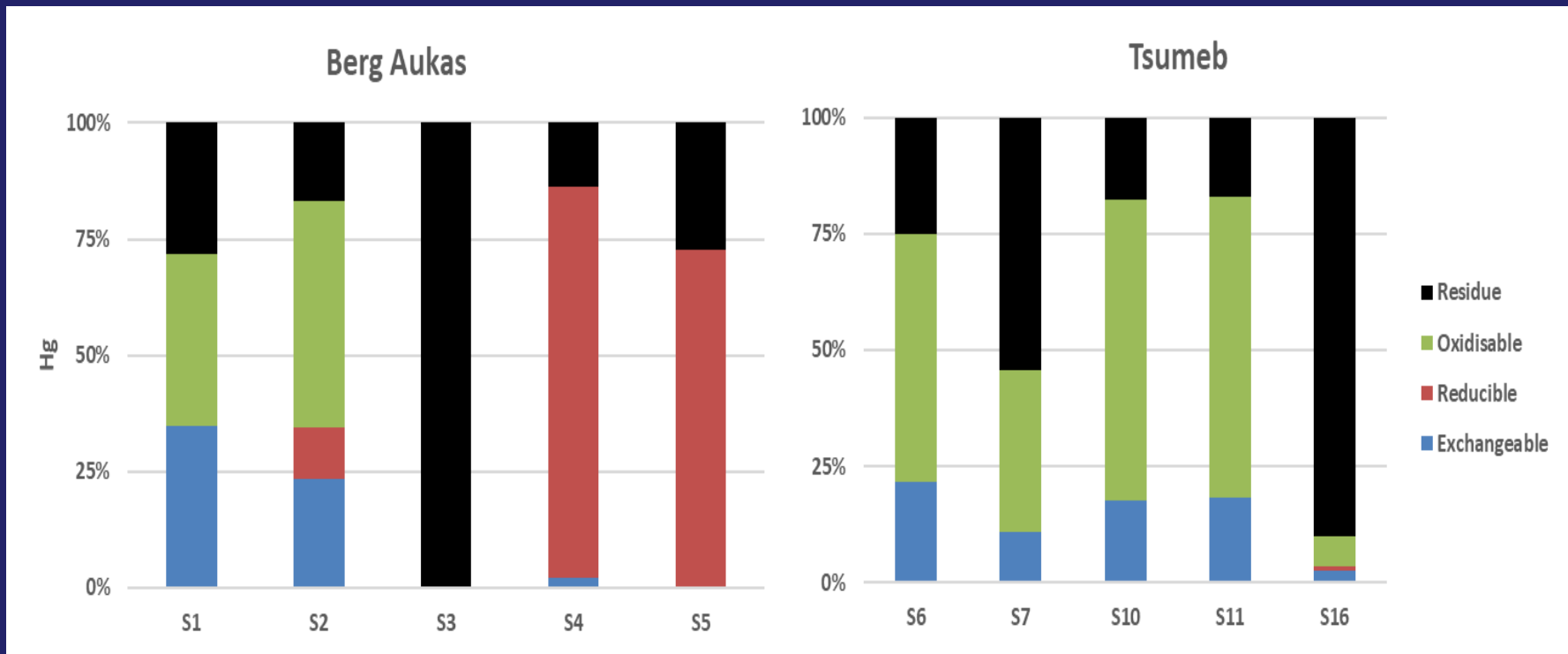


Fig. 7. Hg speciation in soils from Berg Aukas and Tsumeb

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	HgT	ST	S ²⁻	Cl ⁻	NO ₃ ⁻	SO ₄ ²⁻	pH	Ec	F1	F2	F4
HgT	1										
ST	0.716	1									
S ²⁻	0.698	0.756	1								
Cl ⁻	0.638	0.654	0.128	1							
NO ₃ ⁻	-0.093	0.254	0.636	-0.487	1						
SO ₄ ²⁻	0.257	0.622	-0.042	0.845	-0.373	1					
pH	0.458	0.647	0.631	0.110	0.245	0.234	1				
Ec	-0.722	-0.169	-0.610	0.023	-0.093	0.471	-0.289	1			
F1	-0.498	-0.911	-0.663	-0.589	-0.411	-0.599	-0.349	-0.054	1		
F2	0.752	0.782	0.915	0.362	0.522	0.099	0.340	-0.531	-0.793	1	
F4	0.995	0.770	0.708	0.683	-0.077	0.329	0.473	-0.063	-0.567	0.772	1

Table 2. Correlation data between Hg and physico-chemical parameters in tailings

CONCLUSION

This study showed evidence that past mining activities continue to pollute the soils, water and plants in Berg Aukas and Tsumeb. In general, it is observable that the Berg Aukas area is more severely contaminated than the Tsumeb area. Fractionation and correlation data enabled the prediction of the occurrence of several Hg species such as elemental Hg (Hg⁰), inorganic Hg forms (e.g. HgCl₂, HgClOH, Hg(OH)₂, HgS, Hg(SH)₂, etc.) as well as organomercurials. It is believed that the roasting of Hg-S bearing minerals could have led to the formation of elemental Hg (Hg⁰) as per the reaction: HgS(s) + O₂(g) → SO₂(g) + Hg⁰(g). The produced Hg⁰ is being dispersed and oxidised into bioavailable forms that enter the waters used for agricultural purposes in the area. Mining activities are still active in Tsumeb and thus continue to cause ecosystem pollution in the surroundings.

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