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Environmental impact assessment of a Pb, Zn smelter using soil, slag and tree ring elemental and isotopic geochemistry in Kabwe, Zambia

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Due to its historical Pb, Zn, Ag, Cd and Cu mines and associated smelter, Kabwe in Zambia is known to be one of the most polluted cities in the world.

Contamination by Pb, Zn and Cu was assessed in four soil profiles around the smelter and remote locations, using Q-ICPMS for trace metal elemental and Pb isotopic measurements. A sequential extraction procedure (SEP) approach was used to obtain a detailed understanding of the vertical behaviour of the contaminants and its availability for plant uptake. Slags Pb isotopic ratios were also determined. Furthermore, tree rings of local pine trees (Pinus Montezumae) were collected and analysed for the same contaminants and Pb isotopes coupled with C isotopes. Results were compared to the smelter production historical records to assess the viability of these trees as environmental archive.

Results show that contamination is exclusive to the top layers of soil and is greater in soils closer to the smelter, which are highly contaminated (max: 16000 mg/kg Pb; 140000 mg/kg Zn; 600 mg/kg Cu). Remote soils have much lower topsoil concentrations (min: 61 mg/kg Pb; 351 mg/kg Zn; 21 mg/kg Cu). Interestingly, the greatest contaminant concentrations were found in the tree furthest from the source of pollution (max.: Pb, 6.48 mg/kg; Zn, 10.6 mg/kg; Cu, 10.2 mg/kg). Particle size of wind-blown dump dust decreases with distance. A hypothesis is considering that these would be more easily adsorbed and absorbed by tree bark and leaves. This suggests that above-ground tree uptake is more important than soil uptake for the selected elements.

Slag Pb isotopic ratios average at $^{206}Pb/^{207}Pb$ = 1.15; $^{208}Pb/^{206}Pb$ = 2.15; for tree rings; both sites: $^{206}Pb/^{207}Pb$ = 1.15; $^{208}Pb/^{206}Pb$ = 2.13; and in top soils, close to smelter:$^{206}Pb/^{207}Pb$ = 1.15; $^{208}Pb/^{206}Pb$ = 2.12; and in remote location: $^{206}Pb/^{207}Pb$ =1.14; $^{208}Pb/^{206}Pb$ = 2.15. Isotopic ratios confirm the mine and smelter to be the main source of contamination.

Smelter production records show three major shifts in production amount; increase from the late 1950s to early 1970s and a subsequent decrease till the closure of the smelter in 1994 with a peak

in production in the early 1980s. There seems to be a correlation between Pb production and Pb uptake and Pb and C isotopic ratio variations within a 5 to 10 years delay.

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