

Characteristics of Metal(loid)s, Chlorine and Brominated Flame Retardants in Soil from MSW Open Dumping and Burning Site in Kabwe, Zambia

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INTRODUCTION

Metal(loid)s (e.g., Cu, Pb, Zn, As, Cd, Sb, etc.) and chlorine are often contained in municipal solid waste (MSW). Open burning of MSW leads to not only release of these elements but also formation and emission of toxic chlorinated aromatics such as dioxins (Fujimori et al., 2016). As one of the representative classes of brominated flame retardants (BFRs), polybrominated diphenyl ether (PBDEs) are widely used in daily products but have developed into widespread global Persistent Organic Pollutants (POPs) (Li et al., 2016). Hexabromobenzene (HBBz) is one of the novel BFRs and also exists as potential byproduct of decomposition of PBDEs (Zhang et al., 2016). In this study, residue samples (soil/ash mixture) from a MSW open dumping and burning site in Zambia as well as the surface soil in a nearby area were collected and characterized, aiming at investigating the influence of open dumping and burning of MSW on contamination of metal(loid)s, distribution of chlorine (content and speciation) and spread of BFRs (PBDEs and HBBz) to the local environment.

MATERIALS AND METHODS

Ten soil/ash mixture samples at the surface layer along the dumping and burning district were collected, as well as ten surface soil samples from a nearby un-dumped area. Concentrations of 14 metal(loid)s were detected by inductively coupled plasma mass spectrometry (ICP-MS) and atomic emission spectroscopy (ICP-AES). The chlorine concentration in original samples and samples washed with aqueous solution was measured by combustion ion chromatography (CIC). Chlorine speciation was determined by Cl K-edge X-ray absorption near edge structure (XANES) (Mukai et al., 2019). Soxhlet extracts of all the 20 original samples were purified using silica gel column chromatography and analyzed by GCqMS (GCMS-QP2020/GC-EI-qMS, Shimadzu) for PBDEs (22 congeners from Tetra- to Deca-BDE) and HBBz.

RESULTS AND DISCUSSION

Heavy metals such as Cu, Pb, Zn, Sb and Cd showed much higher concentrations in open burning residue samples than in reference soil ($p < 0.05$) (Figure 1A, 1B). Concentrations of different chlorine species in burning site samples were 1-4 orders of magnitude higher than that in reference soil (Figure 1C). Significant positive correlations were found among the five aforementioned metals and chlorine (Figure 1D). Specifically, Aromatic-Cl was also positively correlated with the five metals which may promote the formation of chloro-aromatic compounds (Fujimori et al., 2016).

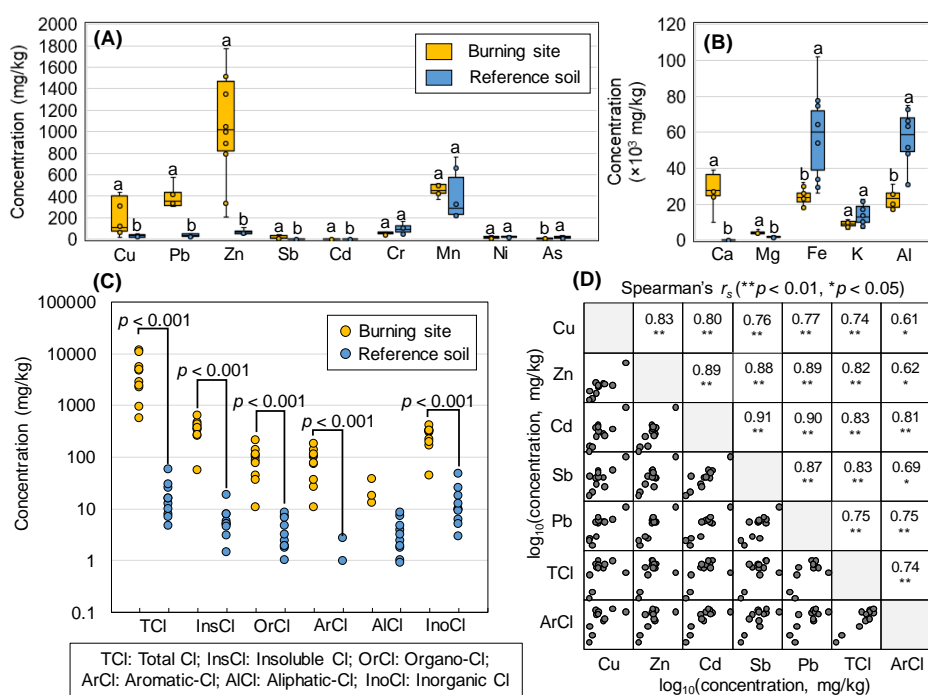


Figure 1 Box-and-whisker plot of metal(loid)s concentration measured by ICP-MS (A) and ICP-AES (B), concentration and speciation of chlorine (C) and correlation between metals and chlorine (D)

PBDEs were detected in only half of the collected samples (Table 1). Most PBDEs came from BDE-209 (82-100%). There was no significant difference between the concentrations of PBDEs and BDE-209 in the two types of samples; whereas, concentrations of HBBz in open burning residues were significantly higher ($p < 0.05$) than those in reference soils.

Table 1 Summary of concentrations of PBDEs and HBBz in two types of samples

(ng/g)	Σ PBDEs			HBBz		
	N (DN ^a)	Range	Mean \pm SD	N (DN)	Range	Mean \pm SD
Burning site	10 (5)	ND ^b -259	33.6 \pm 80.2	10 (7)	ND-110	15.6 \pm 37.2
Reference soil	10 (5)	ND-62.0	6.05 \pm 17.7	10 (2)	ND-3.09	0.33 \pm 0.90

^a DN: detection number, the number of samples detectable for the target compounds; ^b ND: not detected.

CONCLUSION

Open dumping and burning of MSW caused contamination of specific heavy metals (Cu, Pb, Zn, Sb, Cd) and chlorine to the local soil. Concentrations of PBDEs were comparable between the two types of samples. As a novel BFR and potential byproduct of thermal decomposition of PBDEs, HBBz was significantly higher in open burning residues than in reference soils.

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