Revealing the Hidden Toxin of the Bottom Ashes from Open Municipal Waste Burning

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Abstract Bottom ashes caused by open waste burning (OWB) contain a large amount of metal, which can harm human health when exposed directly to humans or leached into the waterways. This study aims to reveal the metal in the bottom ashes and its potential health impact. Laboratory field studies which consist of replication of open burning practice and inductively coupled plasma optical emission spectrometry (ICP-OES) analysis, were used to answer the aims. It is found that the carcinogenic risks (CR) caused by arsenic (As) and cadmium (Cd) from food waste and paper burning are higher through the ingestion pathway. Besides, the hazard index (HI) shows a value of less than 1 for adults and children in all types of waste burning. However, a higher average value for HI is found in the children. This value means that children are the most vulnerable subject to the leaching of bottom ash through the waterways from OWB practices.

Keywords: bottom ashes; metal speciation; open waste burning; risk analysis

1. Introduction

Households, commercial establishments, and institutions in a particular area generate municipal solid waste (MSW). MSW can include a wide variety of materials, including paper, cardboard, food waste, plastic, glass, metal, yard waste, and other items (Pathak et al., 2020). A variety of factors, including population growth, urbanization, and changes in consumption patterns, drive the rapid increase in MSW generation. However, in many developing countries, where the proper waste management systems are limited, people dump and burn their waste in the environment as a free tool to eliminate waste quickly (Ramadan et al., 2022). Open waste burning (OWB), also known as outdoor burning, refers to the burning of municipal waste outdoors in the open air. This practice is generally discouraged because it can release various pollutants into the air, including particulate matter (PM), carbon monoxide, volatile organic compounds, and other harmful substances (Anjum et al., 2021). Most of the studies are studying the metal leaching from incineration ash, wood ash, and electronic waste but a little study evaluated the metal leaching from the open burning of waste (Nikravan et al., 2020; Scussel et al., 2022). Only Gwenzi et al. (2016) evaluate the bottom ash potential of leaching properties of several metals from the open burning ash from a landfill. Therefore, since many OWB practices and waste piles are found on the roadsides, besides the waterways or rivers in many developing countries, the possibility of bottom ashes being flushed into the water environment is higher. Thus, this study aims to estimate the number of heavy metals that could be produced from the bottom ashes and determine their potential risk to human health.

2. Material and Methods

The laboratory work was conducted following Ramadan et al. (2022) procedure. Each composition of burned waste in Semarang City, including (1) backyard waste (branch and twigs), (2) food waste, (3) plastic, (4) cardboard and paper, and (5) textile, were burned. The burning test was repeated three times, and all the bottom ashes were collected and mixed until they reached the requirements for the metal speciation analysis. The bottom ash sample is analyzed using ICP-OES, with the intensity of the signal being measured three times during each of the two investigations. Each investigation requires 4 mL of the diluted sample, injected into the ICP-OES instrument, and a standard solution containing multiple metals. The sample and standard solutions are analyzed using argon gas in the ICP-OES. The intensity and concentration of the metals in the sample are determined by plotting the intensity of the signal against a calibration curve for the standard solution. The potential health risks associated with exposure to metals bound particulate produced by OWB in the form of bottom ash (BA) are estimated by analyzing the hazard index (HI) and carcinogenic risk (CR).

3. Results and Conclusions

The highest metal concentration in the bottom ashes found is Fe, followed by Mn, Zn, and Cu. Cadmium (Cd) and mercury (Hg) are the lowest metal found in the bottom ashes of all types of waste. Fe is found to be higher from paper burning, and Mn is higher from backyard burning. The carcinogenic risks (CR) were found to be higher in the ingestion pathway for both As and Cd, especially from food waste and paper burning, respectively (See Table 1). However, from the results, it is found that the risk value does not exceed the acceptable standard, which is interpreted as insignificant. Some metals have also been found to have a cumulative effect, so future studies should also estimate this matter to obtain a better health risk estimation. Regarding the HI value, it is found that some metals, mainly Fe and Cd, both from cardboard and paper waste burning, can exceed the international limit, which indicates further concern for this issue (See Table 2). Future research should consider the toxicity characteristic leaching procedure (TCLP) test and field test study near a solid waste dump site or roadside open burning to better view inventory and health risk analysis of the water and soil environment.

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Table 1. Carcinogenic Risk Index (Dimensionless)

Recipient	Composition	As	Cd	Cr	Cu	Mn	Pb	Zn	Fe	Hg
Child	Branch and twigs	0.089	0.134	0.080	0.018	0.067	0.099	0.007	0.613	0.050
	Plastic	0.101	0.226	0.096	0.023	0.021	0.258	0.020	0.528	0.033
	Textile	0.110	0.150	0.148	0.031	0.028	0.233	0.146	0.620	0.035
	Cardboard, and paper	0.131	0.788	0.066	0.028	0.031	0.112	0.007	0.754	0.027
	Food waste	0.094	0.277	0.056	0.018	0.048	0.132	0.008	0.443	0.080
Adult	Branch and twigs	0.023	0.048	0.020	0.005	0.017	0.031	0.002	0.194	0.013
	Plastic	0.026	0.081	0.025	0.006	0.005	0.080	0.006	0.167	0.008
	Textile	0.028	0.054	0.038	0.008	0.007	0.073	0.041	0.197	0.009
	Cardboard, and paper	0.033	0.283	0.017	0.007	0.008	0.035	0.002	0.239	0.007
	Food waste	0.024	0.100	0.014	0.004	0.012	0.041	0.002	0.140	0.020

Table 2. Hazard Index (Dimensionless)

Recipient	Composition	As	Cd	Cr	Pb
Child	Branch and twigs	4.37E-06	4.30E-09		

	Plastic	5.02E-05	7.24E-09		
	Textile	5.43E-05	4.80E-09		
	Cardboard, and paper	6.50E-05	2.52E-08		
	Food waste	4.63E-05	8.87E-09		
Adult	Branch and twigs	4.82E-09	3.49E-10	1.20E-07	1.91E-08
	Plastic	5.50E-09	5.88E-10	1.44E-07	5.00E-08
	Textile	5.96E-09	3.90E-10	2.23E-07	4.51E-08
	Cardboard, and paper	7.12E-09	2.05E-09	9.96E-08	2.17E-08
	Food waste	5.08E-09	7.21E-10	8.36E-08	2.55E-08