



Potential for leaching of heavy metals in open-burning bottom ash and soil from a non-engineered solid waste landfill



Willis Gwenzi ^{a,*}, Dorcas Gora ^a, Nhamo Chaukura ^b, Tonny Tauro ^c

^a Biosystems and Environmental Engineering Research Group, Department of Soil Science and Agricultural Engineering, University of Zimbabwe, P.O. Box MP167, Mount Pleasant, Harare, Zimbabwe

^b Department of Polymer Science & Engineering, Harare Institute of Technology, PO Box BE 277, Belvedere, Harare, Zimbabwe

^c Marondera College of Agricultural Science and Technology, University of Zimbabwe, Private Bag 35, Marondera, Zimbabwe

HIGHLIGHTS

- Research on heavy metal leaching from open-burning bottom ash is limited.
- Heavy metal leaching from open-burning ash and landfill soil was investigated.
- Ash had higher pH, Cd, Zn, Mn, Cu, Ni and Pb than landfill soil and control.
- Ash had low risk of heavy metal leaching due to buffered neutral to alkaline pH.
- High pH, Zn, Mn and Cu make ash an ideal soil amendment in sub-Saharan Africa.

ARTICLE INFO

Article history:

Received 19 June 2015

Received in revised form

20 November 2015

Accepted 23 December 2015

Available online 6 January 2016

Handling Editor: Martine Leermakers

Keywords:

Breakthrough curves

Cd

Cu

Mn

Ni

Pb

pH

Zn

ABSTRACT

Bottom ash from open-burning of municipal waste practised in developing countries poses a risk of heavy metal leaching into groundwater. Compared to incineration ash, there is limited information on heavy metal leaching from open-burning ash and soil from non-engineered landfills. Batch and column experiments were conducted to address three specific objectives; (1) to determine aqua regia extractable concentrations of heavy metals in fresh ash, old ash and soil from beneath the landfill, (2) to determine the relationship between heavy metal leaching, initial and final pH of leaching solution, and aqua regia extractable concentrations, and (3) to determine the breakthrough curves of heavy metals in ashes and soil. Aqua regia extractable concentrations of Cd, Zn, Mn, Cu, Ni and Pb were significantly higher ($p < 0.05$) in fresh and old ashes than soil beneath landfill and uncontaminated soil (control). Increasing initial solution pH from 5 and 7 to 9 significantly reduced the mobility of Pb, Zn and Cu but not Cd whose mobility peaked at pH 7 and 9. Concentrations of desorbed heavy metals were not correlated with aqua regia extractable concentrations. Final pH of leachate rebounded to close to original pH of the material, suggesting a putative high buffering capacity for all materials. Both batch and column leaching showed that concentrations of leached heavy metals were disproportionately lower (<5%) than aqua regia extractable concentrations in most cases. The retardation of heavy metals was further evidenced by sigmoidal breakthrough curves. Heavy metal retention was attributed to precipitation, pH-dependent adsorption and formation of insoluble organo-metallic complexes at near-neutral to alkaline pH. Overall, the risk of heavy metal leaching from ash and soil from the waste dump into groundwater was low. The high pH and the presence of Zn, Fe, Mn and Cu make ash an ideal low-cost liming material and source of micronutrients particularly on acidic soils prevalent in sub-Saharan Africa.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Open burning of solid waste is a common practice in developing countries and remote communities in developed countries (UNEP, 2005). These waste disposal practices pose significant environmental and public health risks via atmospheric, soil and

* Corresponding author.

E-mail address: wgwenzi@yahoo.co.uk (W. Gwenzi).

groundwater pollution. Minimizing the risk of groundwater contamination is particularly important in sub-Saharan Africa, where both rural and urban communities rely on groundwater for domestic supplies. Moreover, the risk of heavy metal leaching in ash is also a key determinant of its suitability for beneficiation, e.g. subsequent application as a soil amendment and as construction material.

Literature on heavy metal leaching focuses on incineration ash (e.g. Ménard et al., 2006), coal fly ash (e.g. Inanc et al., 2007), electronic and electrical wastes (e.g. Luo et al., 2011). The bulk of these studies were conducted in developed countries, where properly designed incinerators and engineered landfills are used for waste disposal. By comparison, there is limited information on the risk of heavy metal leaching in open-burning bottom ash in non-engineered landfills used in developing countries. Moreover, contrasting consumer behaviour and waste management practices imply that solid waste in developing countries have unique physical and chemical properties to that in developed countries (Cointreau, 2006). For instance, whereas developed countries practice waste conversion to products, reuse and recycling, co-disposal of mixed hazardous and non-hazardous wastes, followed by open burning are predominant in developing countries. Mixed municipal solid waste, which often comprises of electrical and electronic wastes, construction debris, domestic organic wastes and industrial wastes, has a heterogeneous physical and chemical composition (UNEP, 2005). Hazardous wastes such as electronic and electrical wastes are known to have high concentrations of heavy metals (Luo et al., 2011), which can potentially contaminate soil and water resources. Contrasting waste composition and disposal practices collectively constrain the extrapolation of research findings from developed to developing countries, warranting further complementary investigations in the latter.

Several factors control the speciation and mobility of heavy metals in landfills. High soil organic carbon, phosphates and sequioxides promote adsorption of heavy metals, but other studies have shown that the mobility of heavy metals was coupled to that of dissolved organic carbon (Ashworth and Alloway, 2004). Several laboratory studies investigating heavy metal leaching over a wide range of pH conditions showed that acidic pH enhanced heavy metal leaching, while alkaline conditions promote their retention. On the one hand, the pH of landfill leachate has been shown to be highly variable, ranging from acidic in young landfills to near-neutral and alkaline in old landfills (Tränkler et al., 2005). On the other hand, incineration ash has been reported to be alkaline predominantly due to the presence of carbonates. Other studies showed that combustion/incineration also influences the speciation and mobility of heavy metals (e.g. Ménard et al., 2006). For example, Cu^{2+} and Ni^{2+} were shown to be predominant forms in raw municipal waste, but were reduced to Cu^+ and Ni^+ after combustion (Ménard et al., 2006). Moreover, unlike in incineration, open burning may result in incomplete combustion and in-situ formation of carbon-rich biochar-like material. Biochar has been widely reported to have high adsorption capacity for heavy metals and other contaminants (Beesley et al., 2011). Moreover, old ash from historical burning of solid waste and soil beneath the waste dump may act as sinks for contaminants leached from overlying fresh ash and solid wastes. In non-engineered landfills incorporating regular open burning, these counteracting processes may act simultaneously and control heavy metal leaching in soil and bottom ash. In this regard, one would expect the concentrations and mobility of heavy metals to vary significantly among fresh bottom ash, old bottom ash and soil from the landfill. However, it is unclear which of these processes will have a dominant effect on heavy metal behaviour in ash and soil from non-engineered landfills.

The specific objectives of the current study were: (1) to

determine and compare aqua regia extractable heavy metals in fresh ash, old ash, soil from beneath a waste and uncontaminated soil (control), (2) to determine the relationships between the concentrations of leached heavy metals and organic carbon, pH of the material, initial and final solution pH and aqua regia extractable concentrations, and (3) to determine and compare the breakthrough curves of heavy metals in fresh ash, old ash, soil beneath the dump and uncontaminated soil (control).

2. Materials and methods

2.1. Sampling of ashes and soils

The study included four treatments, (1) fresh ash from recently burnt waste, (2) aged ash that had accumulated over the years from burning of waste, (3) soil from beneath the dump and (4) uncontaminated soil from a nearby crop field (control). Fresh ash, aged ash and soil from beneath the waste were randomly collected from five sampling sites within a non-engineered landfill at the University of Zimbabwe campus in Harare (31°02'56.13" E; 17°46'50.13"S). The landfill has been in operation for over 50 years and waste disposed of includes electronic and electrical waste, office waste paper, domestic waste from residential halls and litter. Waste is burnt every 5–6 weeks to reduce accumulation. Fresh ash from waste burnt three weeks prior to sampling was collected from five selected sites within the dumpsites. About 4 kg samples were collected from each sampling site and mixed to make a 20 kg composite sample. Aged ash was collected from five sampling points within the bottom of the landfill after scrapping off fresh ash and waste. The aged ash was dark in colour, moist and had accumulated over the years as burning of waste is a frequent activity at the dumpsite. Soil beneath the dump was collected at a depth of 35–50 cm depending on the location of the sampling areas. The soil samples were obtained below the aged ash layer of the dump from the five sampling sites. An uncontaminated soil from a nearby field was used as a control.

2.2. Characterization of ash and soils

Particle size distribution, pH, electrical conductivity (EC) and organic carbon (OC) were measured on triplicate samples of fresh ash, old ash, soil beneath the dump and control. Particle size analysis was done using a combination of wet sieving and sedimentation (Gee and Bauder, 1986). Soil pH and electrical conductivity were measured in 1: 5 soil: water suspension using a pH-EC electrode (Rayment and Higginson, 1992). The modified Walkley–Black method was used for determining OC on samples passed through a 0.5-mm sieve (Okalebo et al., 1993).

2.3. Aqua regia extractable concentrations of heavy metals

Ash and soil samples were air-dried, ground and passed through a 2-mm sieve. One-gram samples of each material were digested with 5 mL of aqua regia solution (Alloway, 1995). The soil-aqua regia mixture was heated to 90 °C until almost dry, and then diluted with 20 mL of deionized water. Solutions were allowed to cool and made up to 50 mL with deionized water. The solutions were filtered through a Whatman No. 45 filter paper. The filtrate was assayed for Zn, Cd, Mn, Pb, Fe, Cu and Ni using an atomic absorption spectrophotometer (model: Varian Version 1.13, Australia).

2.4. Batch desorption experiment

Three extracting solutions at pH 5, 7 and 9 were prepared using

Download English Version:

<https://daneshyari.com/en/article/4408009>

Download Persian Version:

<https://daneshyari.com/article/4408009>

[Daneshyari.com](https://daneshyari.com)