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Multivariate analysis of the effects of age, particle size and landfill depth on heavy metals pollution content of closed and active landfill precursors

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ABSTRACT

Multivariate analysis of a heavy metal pollution survey of closed and active landfill precursors was carried out in order to compare environmental risk levels in relation to age, particle size and depth of the precursors. Landfill precursors (77) were collected and analyzed for 15 USEPA toxic heavy metals using ICP-MS. Heavy metals concentrations in closed landfill precursors were significantly higher than those in the active landfill for 11 of 15 heavy metals investigated (closed landfill order: Fe > Al > Mn > Cu > Pb > Ba > Co > Cr > Ni > Cd > As > Se > Ti). Cluster analysis and correlation studies indicated the distribution of the metals was more influenced by landfill precursor size than by depth of the sample. Principal component analysis (PCA) showed that 10 of 15 of heavy metals of both landfill precursors were from similar anthropogenic sources. Heavy metals pollution indices ($I_{geo} > 5$, $EF > 40$ and $CF > 7$) of both active and closed landfill precursors exceeded limits in the order of Zn > Cd > Pb > Cu > Ag, indicating a major potential health risk influenced by age and particle size of precursor. Zn, Cd, Cu and Pb of both landfill precursors exceeded the USEPA set standard for assessment of human health risk for each of the metals (1×10^{-4} to 1×10^{-3}). This study highlights the need for the integration of a clean-up process for precursors from both types of landfill to reduce possible environmental pollution during a reuse process.

1. Introduction

Heavy metal deposition into landfill is of major concern due to the possible complex pathways into the environment and the possible high risk effect on living organism within the landfill areas. Heavy metal contamination from landfills has been attributed to farmland, surface water and underground water pollution (Lu et al., 2010; Chen et al., 2015, Sharifi et al., 2016).

Unlike organic pollutants, heavy metals do not degrade in the landfill and their residual time in a municipal landfill can be for about 150 years if the metal is leached at a rate of 400 mm/year (EU, 2002). This indicates that only a small proportion of the possible heavy metals content of a landfill is reflected in its leachate. Major heavy metals content of the landfill is reflected by landfill precursor which is the solid waste formed as result of the heterogeneous interaction between disposed wastes, climatic conditions and the management practice of the landfill. The growing interest in landfill mining and reuse of landfill precursors as compost (Masi et al., 2014; Rong et al., 2017), landfill covering (Jain et al., 2005) and energy recovery (Quaghebeur et al., 2013) requires an evaluation of heavy metals enrichment level and associated health risks of landfill precursors, as part of a strategy to prevent further deposition of the heavy metals into the environment. Exposure to certain concentrations of heavy metal could lead to diverse health challenges especially for vulnerable people (children and aged), e.g. Cd, As, and Pb induces carcinogenesis of organs like lungs, kidney, bladder and skin (Kamunda et al., 2016).

In Nigeria, heavy metal percolation into wells and underground water within 50–100 m from an active landfill at Olushosun, Lagos, had been reported (Aboyeji and Eigbokhan, 2016). The rapid urbanization in the commercial capital Lagos has also increased pressure on the government to seek alternative reuse of closed landfill precursors, but heavy metal contamination levels and the possible human health risk involved is essential information needed to make an informed decision. Heavy metal concentrations of the landfill within the Lagos area had been largely determined by the soil/fine components of landfill, while the possible contribution of other component of the landfill has been ignored. Jain et al.

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(2013) and Kaartinen et al. (2013) have reported size grouping of landfill precursors as important to understanding pollution assessment and possible reuse option. Multivariate analytical tools have been deployed to measure relationship, impact and association within several symmetrical and asymmetrical environmental components (Lu et al., 2010; Singh & Kumar, 2017). There is also a paucity of published report on the effect of landfill depth and age on the heavy metal pollution indices of landfill precursors.

We report here on a multivariate analysis of heavy metals pollution survey of a closed and active landfill precursors using major pollution indicators (geo accumulation index, I_{geo}; enrichment factor, EF; contamination factor, CF), in order to compare the environmental risk levels in relationship to the age, particle size and depth of the landfill precursors.

2. Material and method

2.1. Sampling locations

The Olusoshun active landfill site is located in the northern part of Lagos Metropolis within the Ojota area of Ikeja Local Government Council, within a Longitude of 6° 35′ 50″E to 6° 36′ 30 “E and Latitude 3° 22 ’ 45 ”N to 3° 23 ’ 30 “N. It has been in operation since November 1992 with an area of 42 ha and receives an average of 8000 metric tons of waste daily (Lawma, 2012). The Abule-Egba closed landfill is located in the Western part of Lagos, under the Alimosho Local Government Council, with an area of about 10.2 ha. It started receiving waste in 1984 and has an estimated 1.3 million metric tons of waste with an average height of 12.5 m. The site had been closed since 2009 (LAWMA, 2012). Detailed site operational activities of the two sites are reported in Adelopo et al. (2017). The two landfills have similar anthropogenic activities around their vicinity with residential, commercial and industrial settlements bordering different ends of the landfill sites. Fig. 1 shows the sampling locations.

2.2. Sampling profile

Sampling for this research was designed to evaluate the first receptor layer (between 5 and 30 cm) of the landfills, which reflect the early changes in the composition of the landfill waste. A shallow landfill sampling covering the whole expanse of the landfill was used to reveal the spatial-temporal nature of heavy metal load of waste components within this landfill layer.

2.3. Sampling procedure

The sites were systematically gridded into seven sampling cells using a procedure described by Resource Conservation and Recovery Act (RCRA) waste sampling technical guideline (USEPA, 2002). A sampling cell was approximately 14,571 m^2 for the closed landfill and 52,857 m^2 for the active landfill. Each cell was located using the GPS and a total of three samples were obtained from each cells at different locations at the following depth: (i) upper-depth between 0 and 15 cm; (ii) mid-depth between 16 and 35 cm; and (iii) low-depth between 36 and 50 cm. Sample collection was achieved using a bucket auger and samples were placed in decontaminated plastic containers. An average of 500 g of sample was

Fig. 1. Map of the sampling area.