Science of the Total Environment 637–638 (2018) 182–190

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

A large-scale field trial experiment to derive effective release of heavy metals from incineration bottom ashes during construction in land reclamation

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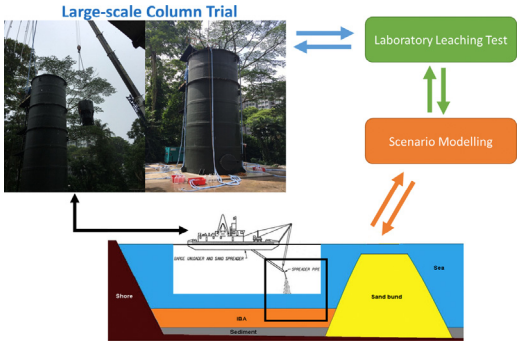
HIGHLIGHTS

- A large-scale field trial with 20 tons of IBA and 320 m^3 of seawater is performed.
- Leaching during dumping of IBA is dissimilar from laboratory batch experiments.
- Distinctive relationships and variations are observed for different heavy metals.
- Potential contributing factors to the uncertainty during field trial are identified.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 22 December 2017
Received in revised form 2 May 2018
Accepted 3 May 2018
Available online xxxx

Editor: Xinbin Feng

Keywords:
IBA
Land reclamation
Heavy metals
Seawater
Leaching

ABSTRACT

Recycling of incineration bottom ashes (IBA) is attracting great interest as it is considered as a vital aspect for closing the waste loop to achieve sustainable development at the growing cities around the world. Various laboratory-testing methods are developed to assess the release potential of heavy metals – one of the most important concerns of using IBA, by reflecting the release conditions of heavy metals from IBA based on the targeted land reclamation application scenarios and corresponding environmental conditions. However, realistic release of the concerned elements in actual application with the presence of complex environment could possibly deviate from the outcomes produced by leaching tests carried out in the laboratory. Hence, a set of large-scale column trial experiments was performed to experimentally determine the effective release of heavy metals, when IBA is used as a filling material in land reclamation. 20 tons of IBA and 320 m^3 of seawater were used in six column trial experiments. The release of 13 heavy metal elements was analyzed through multiple aspects which included kinetics of release, distribution of elements in seawater and the impacts of two different dumping methods, with and without application of a chute. After dumping of IBA into the seawater, almost instantaneous release of heavy metals with uniform horizontal dispersion was observed. Higher concentration of these elements was observed near the bottom of the column, especially when a chute was applied. Comparative analysis was then carried out to establish relationships between the results obtained from the column trial with batch leaching test

Abbreviations: IBA, incineration bottom ashes; MSW, municipal solid waste; DI, deionized water; TC, total carbon; TOC, total organic carbon; CV, coefficients of variation; LP, leaching potential; CT1, IBA collected during column trial 1st dumping experiment; CT2, IBA collected during column trial 2nd dumping experiment; CT3, IBA collected during column trial 3rd dumping experiment; CT4, IBA collected during column trial 4th dumping experiment; CT5, IBA collected during column trial 5th dumping experiment; CT6, IBA collected during column trial 6th dumping experiment.

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https://doi.org/10.1016/j.scitotenv.2018.05.026

carried out in the laboratory. Distinctive relationships were observed for different heavy metals which suggests the need of pursuance of further understanding on leaching of IBA in real application scenario and complex environment.

1. Introduction

Application and recycling of incineration bottom ashes (IBA), a major by-product generated during incineration of municipal solid waste (MSW), is of great interests to close the waste loop (Alam et al., 2017; Lynn et al., 2016; Silva et al., 2017; Yang et al., 2018). In addition, recycling of IBA can improve the sustainability of the landfill as a depository for waste materials. Using IBA as one of the filling materials for land reclamation in conjunction with other materials such as sands, sediments and excavated/dredged materials is considered as a potential large-scale usage of IBA (Astrup, 2007; Guo and Wu, 2017; Patra et al., 2017). However, heavy metals in IBA may be released into the surrounding marine environment through leaching. Therefore, to safeguard the marine environment, it is important that the leachability of IBA is within appropriate regulatory standard. The IBA leachate generated during the contact of seawater must meet the environmental quality criteria. Various leaching criteria and compliance test methods have been applied in different countries for specific scenario to recycle waste materials, but there is so far no specific regulatory standard available for the application of IBA in land reclamation (Dou et al., 2017; Duan et al., 2016; Liu et al., 2015). To develop scientifically sound leaching criteria for this application, a comprehensive assessment is needed to

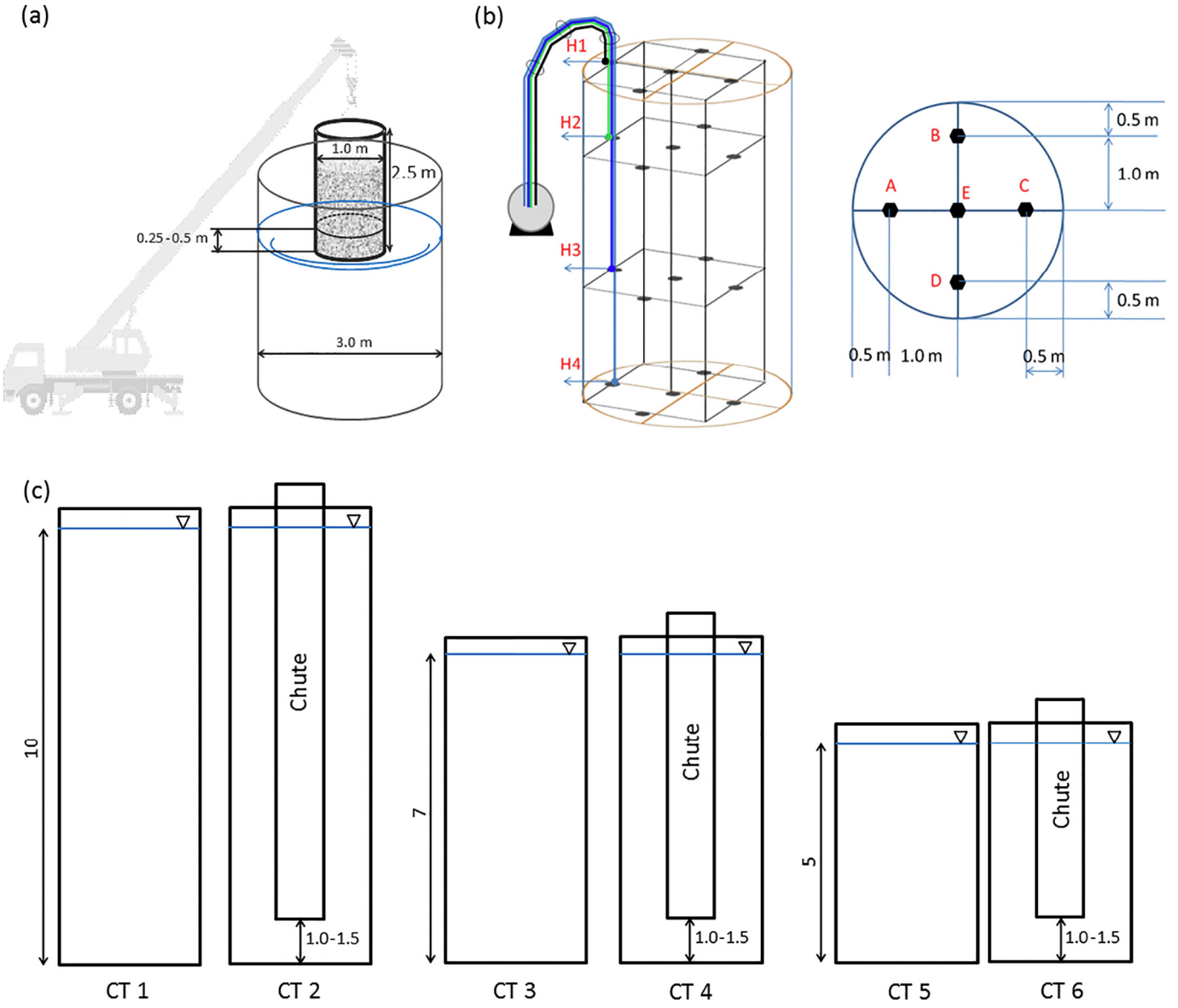

Fig. 1. (a) Container (dumping device) for IBA collection (approximately 3.2 tons of wet IBA) and dropping off. (b) Illustration of sampling device, sampling heights (H1, H2, H3, and H4) and points (A, B, C, D and E). Total of five pumps were in used. (c) Experimental set up for six column trials, CT1–6, with and without chute for three setting of columns with different levels (10 m, 7 m and 5 m) and volumes (70.7 m^3, 49.5 m^3 and 35.3 m^3) of seawater.