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Analysis of heavy metals in Incineration Bottom Ash in Singapore and potential impact of pre-sorting on ash quality

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Abstract

Semakau Landfill, Singapore's only waste landfill, is estimated to be filled completely by 2035. To avert future crisis for a new landfill, it is crucial to divert the incineration ash and utilize it for construction purposes. Understanding characteristics of incineration ash would be the first step towards ash utilization. This paper analyses the chemical and physical characteristics of the bottom ash from a Singapore Incineration Plant via Toxicity Characteristic Leaching Procedure (TCLP) and Scanning Electron Microscope (SEM). These characteristics are used to identify and relate the ash components- heavy metals and unburnt waste, to their responsible sources in the various waste streams in Singapore. This paper also reviews waste streams that should be targeted for pre-sorting of municipal solid waste to improve the ash quality and complement any post-treatment processes for the ash.

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Keywords: Singapore; Incineration bottom ash; Pre-sorting; Recycling; TCLP, Municipal Solid Waste

Nomenclature

MSW	Municipal Solid Waste
SEM-EDS	Scanning Electron Microscopy with Energy Dispersive X-Ray Analysis
TCLP	Toxicity Characteristic Leaching Procedure
L:S	Liquid to Solid ratio

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1. Introduction

Economic and environmental concerns such as shortage of available land for landfill usage, the high cost of construction of landfills [1] and environmental toxicity from incineration ash [2, 3] are drivers for research on diversion of incineration ash away from landfills for construction purposes. Waste generation in Singapore stands at 7.81 million tonnes for the year of 2016 [4]. At nationwide level, 4.77 million tonnes of waste were recycled and successfully diverted from the incineration plants [4], thereby limiting the incineration ash and non-incinerable waste produced to 0.80 million tonnes annually, that is 2,189 tonnes daily [5]. However, Semakau landfill will be able to sustain such an annual ash landfilling trend only till year 2035 [6]. It is imperative to seek alternative methods of ash utilization and subsequent reduction in amount of ash designated for landfill disposal to increase the lifespan of the sole landfill in Singapore.

Incineration ash contains compounds such as lead, cadmium, chromium, copper, zinc, mercury, arsenic. Several of these metals are carcinogens or can cause neurological, hematopoietic effects in humans [7]. Recycled products containing incineration ash may pose a health risk for humans and surrounding ecosystem when there is potential of leaching of these toxic elements. The mineralogical properties of the ash also render it difficult for producing a stable component in building materials [8]. Physical and chemical toxicity characteristics such as these have hindered demand of incineration ash as a construction material. Nevertheless, there have been advances that have allowed for ash utilization in the Singapore landscape such as in the case where the Land Transport Authority in Singapore has successfully tested and approved the use of bottom ash in road pavements since 2010 [9]. However, the issue of minimizing the environmental risk from the bottom ash is still present. Some processes for post-treatment of ash and utilization include recovery of metal scraps from bottom ash, extraction or stabilization of toxic elements when used for construction of pavements, road base, etc. [10]. Another route or pathway of preventing accumulation of toxic elements in incineration ash is by reduction of items that are sources of these toxic elements in the municipal solid waste (MSW) via pre-sorting methods [11, 12]. Pre-sorting of municipal solid waste prior to mass burn incineration eliminates sources of toxic heavy metals [13, 14]. For example, Sommer et al. (1989) reported on lowered Lead levels in ashes from an incineration plant in US because of diverted automobile Lead-acid batteries from the waste stream [11].

Combustible items such as plastics and other pigment uses are responsible for significant contribution of leachable metals such as lead and cadmium in the bottom ash [7]. In Singapore, with plastic recycling rates at 7%, 0.76 million tonnes of plastic were incinerated in 2016 [4]. Waste source reduction of plastics in MSW could lead to a decrease in lead and cadmium concentration in the bottom ash. However, plastics form the dominant fuel source for the incineration process [15, 16]. Drastic reduction of plastics in the feedstock to Waste-to-Energy (WTE) plant could lower the net energy generated – a crucial factor to be considered when comparing benefits of generating cleaner ash versus sustaining the incineration fuel demand. Subsequently, other waste streams need to be targeted to reduce total amount of incineration ash generated and the heavy metal content of the ashes to facilitate higher ash utilization alternatives.

Under the scope of this paper, bottom ash samples were analyzed for their heavy metal content. Leaching of heavy metals from bottom ash were benchmarked against the Singapore landfill leaching criteria. The data on leaching were then compared against metal leaching from natural occurring materials. The metals of higher concentration or leaching risk were identified and their potential waste stream sources were highlighted.

2. Method

The sample incineration bottom ash analysed in this study was collected monthly for 6 months, from a Singapore Incineration Plant. As the bottom ash in Singapore is sent to a post-treatment facility for the recovery of ferrous and non-ferrous metals before it is landfilled, the analysis data for bottom ash in our study is not reflective of the actual end-product ash that is landfilled.