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Recycling of MSWI-bottom ash in paved constructions in Sweden – A risk assessment

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ABSTRACT

This paper presents results from a risk assessment of recycling pre-treated bottom ash from municipal solid waste incineration as a subbase layer in certain asphalt paved constructions in Sweden. Based on a model for assessing environmental and health risks at contaminated areas, previously developed by the Swedish EPA and by the Swedish Geotechnical Institute, target values for total content and porewater concentrations were calculated. Three different construction sizes and geometries were considered; a 1 km long road of 10 and 20 m width, respectively, and an application of 100 × 300 m. Additionally, different technical solutions of the use of bottom as in road embankments were considered. Compared to risk assessments conducted in other countries, target values are generally higher, but in the same order of magnitude. Total lead concentrations in dust potentially emitted during construction and demolition of the bottom ash is identified as a critical factor. It requires particular attention when planning for or carrying out groundwork constructions with pre-treated bottom ash. As exposure to dust and bioavailaibility of lead in bottom ash are likely to be overestimated by the underlying risk model, higher target values for lead in bottom ash should be possible for the envisaged construction purposes without affecting the general risk level. As no data is available on actual dust production and deposition by constructing and demolishing subbase layers of pre-treated bottom ash, this should be a part of future studies in order to narrow down lead target values.

1. Introduction

Municipal solid waste incineration (MSWI) with energy recovery is a crucial part of Sweden's waste management system. Annually, it gives rise to almost 1 Mtonnes of bottom ash (MSWI-BA), which – after pre-treatment by means of metal recovery and carbonation – has a large potential to substitute for natural aggregates in constructions, and, contribute to a circular economy (Swedish Waste Association, 2015; SGI 2006; Swedish Energy Ashes, 2012). Its suitability as a construction material, as well as potential environmental risks and benefits associated with recycling have been studied intensively (see for example Chandler et al., 1997; Saveyn et al., 2014; van Zomeren and van der Sloot, 2013; Tauw, 2011; Olsson et al., 2006; Birgisdottir et al., 2006; Hjelmar et al, 2007). In Sweden, however, bottom ash is mainly used as a filling material below landfill top covers, and, on a smaller scale, as a construction material within the boundaries of waste management facilities.

The Swedish EPA (SEPA) has published guidelines and "maximum contamination levels" for the reuse of granular waste materials in earth construction works in non-bound form (Swedish EPA, 2010, see Saveyn et al., 2014, for a summary in English). It defines "maximum levels" of total contents and leaching corresponding to a level of what is called a "negligible" remaining risk. Two different types of recycling are determined and subject to different "maximum levels": 1) "Free" use, outside environmentally sensitive areas, without regulatory restrictions, i.e. neither necessitating monitoring nor environmental control, including free movement of the waste after the life span of the construction, and 2), use for landfill capping above liner. The recommended maximum

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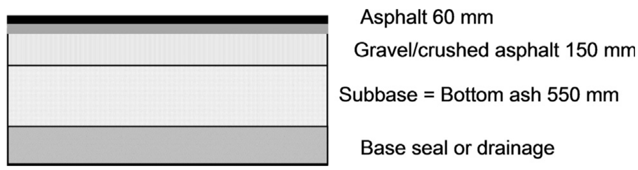

Fig. 1. Schematic cross-section of road construction with MSWI-BA subbase layer.

levels comprise certain heavy metals (total contents and leaching at L/S 0.1 and 10) and total contents of PAH in the waste. Values are consistently lower than acceptance criteria for waste to an inert waste landfill in the EU (EC, 2002). Applied to bottom ash, these "maximum levels" would prevent its recycling with regard to total content of the included potentially hazardous substances (As, Cd, total Cr, Cu, Hg, Ni, Pb, and Zn). The current guidelines do not, however, explicitly take into consideration the effect of low permeable covers on the waste, as would normally be the case when bottom ash is substituted for natural aggregates, for example in a road subbase (see Fig. 1). Consequently, current guidance and environmental risk assessment is not adjusted for the potential effects that construction, maintenance and demolition of a road constructed with bottom ash as a subbase has on potential risks for human health and the environment.

This study aims to address the lack of specific guidance for recycling pre-treated bottom ash as a subbase in constructions in Sweden, by adjusting a previously developed risk assessment model to specified, typical default recycling cases and by calculating limit values for total contents and leachate concentrations, potentially allowing for acceptable levels for environmental and human health risks.

2. Methods and material

2.1. Risk assessment model

The calculation of risk based target values was carried out with SEPA's risk assessment model for contaminated areas (Swedish EPA, 2009, Swedish EPA, 2016). A conceptual deviation from SEPA's model is that the source of contamination is placed above surface, rather than in the subsurface (see Fig. 2a). The considered pathways are dust emission (A), dust deposition (B), leaching to the aquifer (C) of width b + x and depth z, mixing and dilution of leachate from the construction and subsequent leaching from groundwater to lake or stream (D), to the point of compliance (POC_{GW}), all of which are indicated in Fig. 2a in cross section and Fig. 2b in aerial view.

The potential risks to human health by dust exposure during construction, maintenance and demolition is calculated by means of an altered model from Bendz et al. (2009), for the following exposure scenarios:

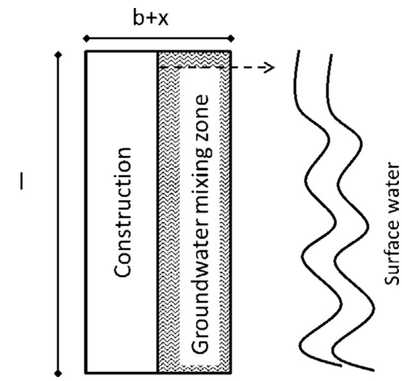

Fig. 2b. Aerial view of conceptual risk assessment model.

- Dust inhalation
- Dust ingestion
- Skin exposure to dust
- Ingestion of vegetables exposed to dust deposition

The health risk based target values, e.g. the concentration of a substance that is unlikely to cause harm in humans exposed to dust, were calculated by means of toxicological reference values, and mainly derived from Swedish EPA (2009). For the exposure pathway "inhalation of dust", reference concentrations in ambient air were used. For ingestion, skin contact and ingestion of vegetables reference concentration for oral intake were utilized.

Exemplified for dust inhalation, target values are calculated by means of Eq. (1):

$$C_{id,fas} = \frac{RfC}{C_{d,fas}} \cdot 10^6$$

where $C_{id,fas}$ denotes the target value for contaminant *i* in dust for either construction, maintenance or destruction (*fas*) so that the assumed dust concentration ($C_{d,fas}$) does not exceed a reference concentrations (*RfC*, integrated for lifetime in case of cancerogenic substances, in this case As, benzo(a)pyrene, PAH M and L).

For every exposure pathway, a specific target value was calculated for two receptors, adults and children. The final health risk based target values were derived from weighted distributions of values for the most sensitive receptor (child). These were adjusted for exposure from other sources (50% of the target value has to be accounted for by other sources, except for lead, cadmium and mercury; 80% of the target value has to be "reserved" for other sources, in line with SEPA's risk assessment model).

Apart from risks to human health, environmental risks for soil, groundwater and surface water due to leaching and transport of contaminants during the double life span of the construction were

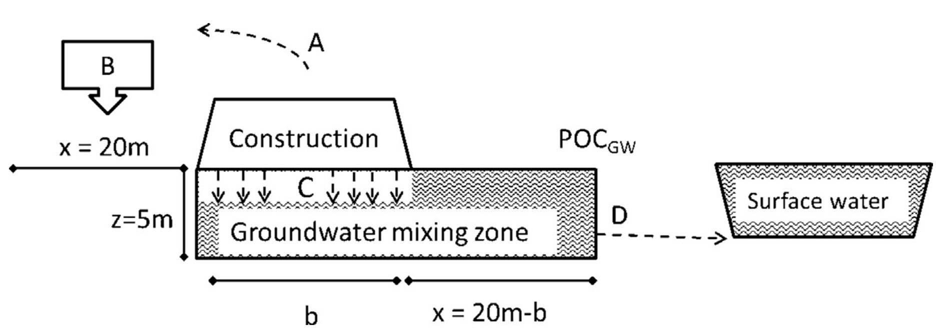

Fig. 2a. Cross section of conceptual risk assessment model.