ARTICLE IN PRESS

Waste Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

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

Combined disc pelletisation and thermal treatment of MSWI fly ash

Florian Huber [a,*], Hannes Herzel [b], Christian Adam [b], Ole Mallow [a], Dominik Blasenbauer [a], Johann Fellner [a]

[a] TU Wien, Institute for Water Quality and Resource Management, Karlsplatz 13/226, 1040 Vienna, Austria

[b] Bundesanstalt für Materialforschung und prüfung (BAM), engl. Federal Institute for Materials Research and Testing, Division Thermochemical Residues Treatment and Resource Recovery, Unter den Eichen 87, 12205 Berlin, Germany

ARTICLE INFO

Article history:
Received 17 October 2017
Revised 11 December 2017
Accepted 13 December 2017
Available online xxxx

Keywords:
Fly ash
Waste incineration
Combustion residues
Thermal treatment
Agglomeration

ABSTRACT

An environmentally friendly and cost efficient way for the management of municipal solid waste incineration (MSWI) fly ash represents its thermal co-treatment together with combustible waste. However, the safe introduction and storage of MSWI fly ash in the waste bunker is challenging and associated with severe problems (e.g. dust emissions, generation of undefined lumps and heat in case of moistened MSWI fly ash). Therefore, the aim of this study is to investigate the suitability of pelletisation as a pretreatment of MSWI fly ash. In particular, MSWI fly ash was characterised after sampling, pelletisation and thermal treatment and the transfer of constituents to secondary fly ash and flue gas was investigated. For this purpose, MSWI fly ash pellets with a water content of about 0.15 kg/kg and a diameter of about 8 mm have been produced by disc pelletiser and treated in an electrically heated pilot-scale rotary kiln at different temperatures, ranging from 450 °C to 1050 °C. The total contents of selected elements in the MSWI fly ash before and after thermal treatment and in the generated secondary fly ash have been analysed in order to understand the fate of each element. Furthermore, leachable contents of selected elements and total content of persistent organic pollutants of the thermally treated MSWI fly ash were determined. Due to the low total content of Hg (0.7 mg/kg) and the low leachate content of Pb (<0.36 mg/kg), even at the lowest treatment temperature of 450 °C, thermally treated MSWI fly ash pellets can be classified as non-hazardous waste. However, temperatures of at least 650 °C are necessary to decrease the toxic equivalency of PCDD/F and DL-PCB. The removal of toxic heavy metals like Cd and Pb is significantly improved at temperatures of 850 °C, 950 °C or even 1050 °C. The observed metal removal led to relatively high contents of e.g. Cu (up to 11,000 mg/kg), Pb (up to 91,000 mg/kg) and Zn (up to 21,000 mg/kg) in the secondary fly ash. This metal enriched secondary fly ash might represent a potential raw material for metal recovery (e.g. via acidic leaching). Due to the high content of total dissolved solids observed in the leachate of thermally treated MSWI fly ash pellets, a wet extraction procedure is suggested to enable its safe disposal at non-hazardous waste landfills.

1. Introduction

Incineration is an effective option for the management of MSW (municipal solid waste), as it decreases the mass and volume of material that has to be disposed of at a landfill and enables the utilisation of energy from MSW for the generation of electricity or district heating. Apart from bottom ash, which accounts for about 25% of the MSW mass inserted into a grate furnace, about 3% of the inserted mass emerges as fly ash (Morf et al., 2000). Fly ash can be defined as "*particulate matter carried over from the combustion chamber and removed from the flue gas stream prior to addition of any type of sorbent material*" (Chandler et al., 1997) and constitutes a hazardous waste that has to be handled appropriately.

State of the art management options for MSWI (municipal solid waste incineration) fly ash comprise disposal at underground deposits (Doka, 2003; Quina et al., 2008) or, after stabilisation with cement, disposal at non-hazardous waste landfills (Polettini et al., 2001; Quina et al., 2008). Both options are costly and require landfill space (either underground or above ground). In case of stabilisation, a considerable amount of cement is necessary, resulting in emissions from cement production (Salas et al., 2016). Consequently, in recent years several studies investigating the thermal treatment of MSWI fly ash as an alternative management option have been conducted (Guohua et al., 2012; Li et al., 2015; Sobiecka, 2015; Sobiecka and Szymanski, 2014; Wang et al., 2008, 2015; Zupančič et al., 2012).

However, due to their high energy demand the above-mentioned thermal treatment processes fail to represent a cost-effective

* Corresponding author.
E-mail address: florian.huber@tuwien.ac.at (F. Huber).

https://doi.org/10.1016/j.wasman.2017.12.020
0956-053X/

Please cite this article in press as: Huber, F., et al. Combined disc pelletisation and thermal treatment of MSWI fly ash. Waste Management (2017), https://doi.org/10.1016/j.wasman.2017.12.020

treatment and disposal option (Huber et al., 2017a), which has so far impaired the wide-scale implementation of thermal MSWI fly ash treatment. Lately, a thermal co-treatment of MSWI fly ash together with combustible hazardous waste in a rotary kiln incinerator was suggested (Huber et al., 2016). In this previous study, MSWI fly ash from a grate furnace was moistened with water to avoid dust emissions during transport. Subsequently, the ash was unloaded into the bunker of a rotary kiln incineration plant and treated in the kiln at temperatures of 850 °C. Almost the entire MSWI fly ash mass inserted into the rotary kiln was transferred to the bottom ash of the rotary kiln incinerator. Volatile heavy metals like Hg and Cd were mainly transferred to the scrubber water and rotary kiln fly ash, respectively, and thereby phased out. Despite the transfer of considerable amounts of non-volatile heavy metal compounds from MSWI fly ash to rotary kiln bottom ash, the bottom ash still complies with the legal limits for non-hazardous waste landfills in Austria (Huber et al., 2016) and the environmental impact of this co-treatment is lower than that of MSWI fly ash stabilisation with cement and thermal treatment in a separate furnace (Huber et al., in press).

Nevertheless, the previous studies mentioned above do not reveal, if thermal treatment of MSWI fly ash is sufficient to create a material that fulfils the criteria for disposal at non-hazardous waste landfills. So far only the mixture of thermally treated MSWI fly ash and rotary kiln bottom ash (generated from hazardous waste incineration) was analysed, as both residues arise together. The rotary kiln fly ash constitutes a hazardous waste anyway independent of the thermal co-processing of MSWI fly ash. Another shortcoming of the previous work is that large lumps of hardened MSWI fly ash were generated in the waste bunker due to setting reaction taking place in moistened fly ash (similar to cement paste) and the temperature in the waste bunker locally increased due to these exothermic reactions, which might pose a safety risk. Neither the hardening of MSWI fly ash nor the temperature increase is acceptable in routine operation. One possible solution for these two problems could be the agglomeration of MSWI fly ash prior to its thermal co-treatment together with combustible waste.

Agglomeration of MSWI fly ash in order to obtain particles of a larger size is already known in the literature. Colangelo et al. (2015) applied a double step cold bonding pelletisation with cement addition to MSWI fly ash in order to produce lightweight aggregates for construction purposes. Nowak et al. (2010) already combined the agglomeration of MSWI fly ash with thermal treatment, but they used a flat die press for agglomeration instead of a pelletising disc and added $CaCl_2$ to the ash.

The objective of the present work is, therefore, the assessment of combined disc pelletisation and thermal treatment of MSWI fly ash without addition of further substances in pilot-scale experiments. The particular research questions to be addressed are:

- Which operation conditions are necessary during pelletisation in order to achieve pellets best suitable for further processing?
- What is the chemical composition of thermally treated MSWI fly ash pellets (total and leachable element contents)?
- How do the MSWI fly ash pellets and their constituents partition between treated MSWI fly ash pellets, dust carried by the flue gas during thermal treatment (secondary fly ash) and flue gas?
- How do the operational conditions of the thermal treatment influence the mass and composition of treated MSWI fly ash pellets and secondary fly ash?

2. Materials and methods

2.1. MSWI fly ash

The fly ash used for the investigation was collected at a MSW incinerator with grate furnace. The air pollution control system at this plant comprises an activated coke injector, fabric filters, a two-stage scrubber and a selective catalytic reduction device. About 1000 kg of MSWI fly ash were collected and stored in big bags prior to use. Six random samples were taken from this MSWI fly ash batch and analysed for total content and leachate content. The fly ash from this plant generally exceeds the legal limits for non-hazardous waste landfills in Austria concerning the parameters Hg total content, total dissolved solids as well as and Pb in the leachate.

2.2. Pelletisation

The pelletisation process is illustrated in Fig. 1. MSWI fly ash was mixed and moistened with water in a ploughshare mixer and subsequently pelletised using a pilot scale pelletising disc with a diameter of 1.2 m. Additional water was sprayed onto the MSWI fly ash as needed and no other additives were used.

The mass flows of MSWI fly ash and water were varied in order to find suitable operation conditions (no dust emissions and acceptable consistency of the pellets). At a mass flow of 300 kg/h a batch of about 400 kg of pellets with a water content of about 0.15 kg/kg and an average diameter of about 8 mm was produced. The pellets were filled into big bags and aged until the experiments on thermal treatment were conducted. Six random samples were taken from this pelletised MSWI fly ash batch and analysed for total and leachate contents. Additionally, the mechanical properties of the MSWI fly ash pellets were measured.

2.3. Thermal treatment

2.3.1. Thermal treatment in a muffle furnace

Pelletised fly ash was filled into corundum crucibles and weighted on an analytical balance. Filled crucibles were heated in a muffle furnace at 450 °C, 750 °C and 1050 °C for 10 min, 30 min and 60 min. After thermal treatment the mass of the pelletised fly ash was measured and the chemical composition of the treated fly ash pellets was determined as described in 2.4. A concentration factor was calculated for each sample (corresponding to a specific temperature and residence time) by dividing the mass of the pellets prior to thermal treatment by the mass of the pellets after thermal treatment. The total content of selected elements in the fly ash pellets before and after thermal treatment was used to find suitable tracer elements that are not transferred to the gas phase. This is the case when the ratio of the concentration of the element after thermal treatment to the concentration before thermal treatment is identical to the concentration factor determined for the sample mass.

2.3.2. Thermal treatment in a rotary kiln

Thermal treatment was conducted in an electrically heated pilot-scale rotary kiln at different temperatures (450 °C, 550 °C, 650 °C, 750 °C, 850 °C, 950 °C and 1050 °C) and angles (2°, 3° and 6°). The higher the angle of the rotary kiln the lower was the residence time of the pelletised MSWI fly ash. The heated part of the rotary tube was 1.5 m long (total length 2.0 m). The rotary tube had an inner diameter of 0.2 m, consisted of a high temperature nickel/chromium alloy (Nicrofer 6025 HT) and was rotating at 2 min^{-1}. Pressurised air was injected into the kiln with a relative flow of about 1 Nm^3/kg MSWI fly ash pellets and the flue gas from the kiln was sucked into a scrubber prior to release into the atmosphere. Pelletised MSWI fly ash was transported into the kiln by a conveyer screw rotating at constant speed. At 1050 °C it was only possible to conduct an experiment at an angle of 6° because of deformation of the conveyer screw that occurred at high temperatures and long treatment times associated with angles of 2° and 3°.

Please cite this article in press as: Huber, F., et al. Combined disc pelletisation and thermal treatment of MSWI fly ash. Waste Management (2017), https://doi.org/10.1016/j.wasman.2017.12.020