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SUSTAINABLE MANAGEMENT OF FLY ASHES FROM WASTE INCINERATION

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Introduction

The main goals of waste management are the protection of humans and the environment from the hazards potentially caused by waste and the conservation of resources. A treatment option for municipal solid waste (that is not separated at source) in line with these goals is waste incineration (Brunner and Rechberger, 2015). However, about 25 % of the waste input into a waste incineration plant arise as bottom ash and about 3 % of the waste input arise as fly ash (Morf et al., 2000). This fly ash constitutes a hazardous waste and has to be disposed of accordingly.

There is a multitude of different utilisation and disposal options for municipal solid waste incineration (MSWI) fly ash. The most common ones are stabilisation with cement, which allows disposal at non-hazardous waste landfills, and disposal at underground deposits, while recovery of secondary raw materials from MSWI fly ash has awoken more and more interest (Quina et al., 2018). As all of the available MSWI fly ash management options are associated with various disadvantages, an innovative process for the treatment of MSWI fly ash is presented. This process comprises the thermal co-treatment of MSWI fly ash together with combustible waste in an already existing MSWI plant.

Materials and methods

In a large-scale experiment, up to 300 kg moistened fly ash per Mg of combustible waste were treated in a rotary kiln hazardous waste incinerator for 102 h. The inserted MSWI fly ash as well as bottom ash, fly ash and scrubber water from the rotary kiln were sampled and chemically analysed (Huber et al., 2016).

The moistening of fly ash effectively prevented dust emissions during transport and storage. However, hydration reactions in the moistened material caused a temperature increase and formation of lumps of hardened fly ash in the waste bunker, which both impair the continuous and safe operation of the incinerator. As a possible solution to this problem, agglomeration was investigated as pretreatment prior to insertion in the waste bunker. About 400 kg of pelletised MSWI fly ash were produced and treated in a pilot-scale electrically heated rotary kiln at different temperatures and angles. The original fly ash, fly ash pellets (prior and after treatment) and secondary fly ash collected by a filtering device were sampled and chemically analysed. Furthermore, physical tests of the fly ash pellets were performed (Huber et al., 2018a).

Based on the recorded mass flows and the results from the chemical analysis of the above mentioned experiments, transfer coefficients on goods and substance level were established.

The experimental data was used to determine the environmental impact of thermal co-treatment of MSWI fly ash together with combustible waste by life cycle assessment (LCA). In order to compare the presented process with the state of the art, a total of 7 different MSWI fly ash management scenarios (comprising underground deposit, stabilisation with different amounts of cement, metal recovery, chloride salt recovery, thermal treatment in furnaces fueled by coal, natural gas or combustible waste and utilisation in cement clinker production) were established and modelled. The life cycle inventory data was sourced from ecoinvent database V3.2 (2015). The life cycle impact assessment was conducted using the ReCiPe model (Hierarchist perspective) (Goedkoop et al., 2009). The impact in all midpoint and endpoint impact categories was calculated for two different timeframes (100 a, infinite) (Huber et al., 2018b; Huber and Fellner, 2018).

Uncertainty analysis was performed by Monte Carlo simulation (MCS) and an discernibility analysis according to Clavreul et al. (2012) was conducted.

Results and Discussion

The material flows determined in the large-scale and pilot-scale experiments suggest that more than 90 % of the inserted MSWI fly ash are bound into the bottom ash of the rotary kiln.

The results of the chemical analysis indicate that the addition of MSWI fly ash to the waste input increased the Cl content of bottom ash by about 75 % (+3,700 mg/kg). As no other significant changes in bottom ash composition and leachability were detected, the bottom ash still complied with all legal limits for non-hazardous waste landfills.

The pilot-scale experiments demonstrated that the transfer coefficients of certain elements (Cd, Cu, Hg, Pb, Zn) were larger at higher temperatures. Yet, treatment at 450 °C for about 10 min was already sufficient to generate a non-hazardous waste from MSWI fly ash. Notably, the leachate content of Ag, As, Cd, Co, Cu, Hg, Ni, Pb, Sb and Sn was decreased by the pelletisation process and even further decreased to close to 0 by the subsequent thermal treatment.

Chemical analysis of the secondary fly ash generated in the pilot-scale experiments revealed that this residue is enriched in Cu (up to 11,000 mg/kg), Pb (up to 91,000 mg/kg) and Zn (up to 21,000 mg/kg), depending on the treatment temperature. Due to this high metal concentration, secondary fly ash could have a considerable potential for resource recovery, e.g. by acidic leaching (Fellner et al., 2015; Schlumberger, 2010).

The aggregated overall impact is lowest (close to 0) for metal recovery by FLUREC process, mainly due to the benefit in human toxicity and metal depletion caused by production of secondary metals and the low impact in most other midpoint impact categories. The total environmental impact is especially high for the thermal treatment in coal-fired furnace and utilisation in cement kiln with salt recovery mainly due to the high consumption of hard coal and natural gas, respectively. This is in agreement with the findings of Fruergaard et al. (2010), which already state that thermal treatment of MSWI fly ash has a very high environmental impact due to the high energy demand. In contrast, the environmental impact of thermal co-treatment of MSWI fly ash together with combustible waste is in many midpoint and all endpoint impact categories significantly lower compared to thermal treatment in a separate furnace. Therefore, it could be shown that the presented process provides a more environmentally friendly option than other thermal treatment processes. Furthermore, the environmental impact of the new process is also lower than many other common disposal options for MSWI fly ash, e.g. stabilisation with cement. The low environmental impact of metal recovery as determined by LCA is in line with the results of Bösch et al. (2011).

Conclusions and outlook

It could be demonstrated that co-treatment of MSWI fly ash together with combustible waste in an existing waste incinerator represent a feasible management option. Pelletisation of MSWI fly ash prior to its thermal treatment is a promising pretreatment process that can facilitate the introduction of fly ash into the incinerator and thereby ensure its continuous operation. Due to the transfer of volatile heavy metals, effective decontamination of MSWI fly ash takes place and the remaining material (transferred to the bottom ash) complies with legal limits for non-hazardous waste landfills after treatment.

Yet, the combination of pelletisation and thermal treatment of MSWI fly ash was only conducted in an electrically heated pilot-scale kiln without the addition of combustible material. Consequently, further investigations on the co-treatment of MSWI fly ash pellets and combustible waste are advisable in order to confirm the results presented. As all experiments carried out so far were performed using rotary kilns, future experiments should also be conducted in grate furnaces, which constitute the most common type of furnace used in MSWI.

The transfer of volatile metals (e.g. Cd, Cu, Pb and Zn) to secondary fly ash is not only a mechanism for decontamination of the bulk of the material but also leads to higher concentrations of these elements in the secondary fly ash. As metal recovery is only economically feasible for fly ashes with very high Zn concentrations, combined pelletisation and thermal co-treatment together with combustible waste can be used to generate residues with a higher metal concentration and subsequently recover these metals at acceptable costs. The environmental impact assessment performed showed that the newly developed MSWI fly ash treatment and disposal process is preferable over stabilisation with cement and, thus, contributes to the goals of waste management, protection of humans and the environment and conservation of resources.

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References:

Bösch, M.E., Haupt, M., Hellweg, S., 2011. Ökobilanzielle Untersuchung der sauren Wäsche von KVA Flugasche in der Schweiz (Life cycle assessment investigation of acidic washing of MSWI fly ash in Switzerland).

Brunner, P.H., Rechberger, H., 2015. Waste to energy – key element for sustainable waste management. Waste Manag. 37, 3–12. https://doi.org/10.1016/j.wasman.2014.02.003

Clavreul, J., Guyonnet, D., Christensen, T.H., 2012. Quantifying uncertainty in LCA-modelling of waste management systems. Waste Manag. 32, 2482–2495. https://doi.org/10.1016/j.wasman.2012.07.008

ecoinvent-center, 2015. ecoinvent database v3.2.

Fellner, J., Lederer, J., Purgar, A., Winterstetter, A., Rechberger, H., Winter, F., Laner, D., 2015. Evaluation of resource recovery from waste incineration residues – The case of zinc. Waste Manag. 37, 95–103. https://doi.org/10.1016/j.wasman.2014.10.010

Fruergaard, T., Hyks, J., Astrup, T., 2010. Life-cycle assessment of selected management options for air pollution control residues from waste incineration. Sci. Total Environ. 408, 4672–4680. https://doi.org/10.1016/j.scitotenv.2010.05.029

Goedkoop, M., Heijungs, R., Huijbregts, M., De Schryver, A., Struijs, J., van Zelm, R., 2009. ReCiPe 2008 – a Life Cycle Impact Assessment Method which Comprises Harmonised Category Indicators at the Midpoint and the Endpoint Level.

Huber, F., Blasenbauer, D., Mallow, O., Lederer, J., Winter, F., Fellner, J., 2016. Thermal co-treatment of combustible hazardous waste and waste incineration fly ash in a rotary kiln. Waste Manag. 58, 181–190. https://doi.org/10.1016/j.wasman.2016.09.013

Huber, F., Fellner, J., 2018. Integration of life cycle assessment with monetary valuation for resource classification: The case of municipal solid waste incineration fly ash. Resour. Conserv. Recycl. 139, 17–26. https://doi.org/10.1016/j.resconrec.2018.08.003

Huber, F., Herzel, H., Adam, C., Mallow, O., Blasenbauer, D., Fellner, J., 2018a. Combined disc pelletisation and thermal treatment of MSWI fly ash. Waste Manag. 73, 381–391. https://doi.org/10.1016/j.wasman.2017.12.020

Huber, F., Laner, D., Fellner, J., 2018b. Comparative life cycle assessment of MSWI fly ash treatment and disposal. Waste Manag. 73, 392–403. https://doi.org/10.1016/j.wasman.2017.06.004

Morf, L.S., Brunner, P.H., Spaun, S., 2000. Effect of operating conditions and input variations on the partitioning of metals in a municipal solid waste incinerator. Waste Manag. Res. 18, 4–15. https://doi.org/10.1034/j.1399-3070.2000.00085.x

Quina, M.J., Bontempi, E., Bogush, A., Schlumberger, S., Weibel, G., Braga, R., Funari, V., Hyks, J., Rasmussen, E., Lederer, J., 2018. Technologies for the management of MSW incineration ashes from gas cleaning: New perspectives on recovery of secondary raw materials and circular economy. Sci. Total Environ. 635, 526–542. https://doi.org/10.1016/j.scitotenv.2018.04.150

Schlumberger, S., 2010. Neue Technologien und Möglichkeiten der Behandlung von Rauchgasreinigungsrückständen im Sinne eines nachhaltigen Ressourcenmanagements (New Technologies and Possibilities for the Treatment of Flue Gas Cleaning Residues to Achieve Sustainable Resource Management), in: KVA-Rückstände in Der Schweiz - Der Rohstoff Mit Mehrwert (MSWI Residues in Switzerland - A Resource with Added Value). Swiss Federal Office for the Environment (FOEN), Bern.