Incineration ashes – environmental concerns, management and final disposal

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Introduction

Reduction of the amount of biodegradable waste that is deposited in landfills now is a global challenge. In the European Union, the council directive on landfilling of waste (1999) stimulates the member states to implement measures for reduction of biodegradable waste, in particular recycling, composting, biogas production and energy recovery from waste.

The incineration process itself reduces the waste mass of municipal solid waste to approximately 1/3, and the volume to approximately 1/6. At the same time, the inorganic elements are concentrated up in the residues, and some new mineral phases are formed in the ashes which bring upon new environmental concerns.

Primary disposal / utilization routes for residues in Europe

The typical disposal routes for incineration residues from MSWI grate-fire incineration installations in Europe are shown in Table 1. Efforts to utilize the bottom ash as a construction material were not always successful. Further, the utilization in road construction is restricted to some upgraded sieve fractions. Even in case of upgrading/utilization, the fine fraction from treatment of bottom ash has to be deposited in landfills.

Table 1: Primary disposal routes for MSWI incineration residues in Europe

Residue / ash	Amount per t of input waste	Typical disposal routes in Europe
Bottom ash	220 – 280 kg	Primary disposal route: Disposal in monofills Or disposal in other landfills, or utilization in road construction
Fly ash / filter ash	Approx. 30 kg	Subsurface disposal Solidification and subsequent disposal in landfills Mixing with bottom ash and disposal in landfills
APC residues	Approx. 10 kg	Subsurface disposal, some utilization of gypsum-containing APC residues

Reactions and environmental concerns of landfilling ashes

In nearly all of the installations, bottom ash is cooled down to ambient temperature by water with the use of a quenching basin (quenching pool). Soon afterwards, lime and other inorganic compounds formed by the incineration process start to react with water. Due to the chemical reaction of lime (hydration reaction), the ash becomes very alkaline (pH>12), and the high pH value may mobilize some of the heavy metals, particularly copper (Cu) and lead (Pb). As a consequence of the high pH and the potential for heavy metal release, leachate from bottom ash monofills has to be collected and treated.

Another negative effect of the high pH value is the subsequent oxidation of aluminium (Al). The metallic Al particles contained in the bottom ash react with dissolved alkali (OH-), and hydrogen gas (H2) is formed thereby. The formation of H2 is accompanied with high risks during transport and landfilling of bottom ash, as a mixture of H2 and air is explosive.

The reactions described above are exothermal, that means much heat is generated by lime hydration and Al oxidation. As a consequence, the bottom ash heats up. Temperatures up to 95oC were observed in ash monofills in Bavaria (Germany). Our own data from Austria indicate temperatures up to 65oC, but it is suggested that this is not the maximum for the bottom ashes from Austria. Further, the temperature may depend on the degree of Al recovery before landfilling. The main risks associated with the heat formation are detoriation /deformation of plastic liners and water loss in geomembranes and clay liners, which may cause cracks and a significant increase of the permeability of the liner. Further, plastic pipes (PE, PP) used for collection of leachate will collapse under the influence of high pressure and increased temperatures. These liner/drainage damage risks are of high concern if "young" bottom ash is deposited directly above the base lining system of a landfill.

Fly ashes from waste incineration contain highly-concentrated (and to some extent toxic, for example Pb, Cd, Sb) metal compounds mostly in a water-soluble state, and therefore have to be solidified or mixed with bottom ash before disposal in congenital landfill. Additionally, stringent criteria and monitoring protocols for solidification / evaluation of long-term emissions have to be applied.

State-of-the-art of bottom ash utilization in Europe

The description of the state-of-the art described below is based on the studies of SCHARFF, 2006, CRILLESEN & SKAARUP, 2006, CRILLESEN, 2009 and our own data from Austria, 2011.

Country	Sieving and Fe recovery	Recovery of non-iron metals (Al, Cu)	Passive ageing (Storage)	Some chemical treatment or solidification a)
Austria	X	X	occasional	occasional
Belgium	X	occasional		
Denmark	X	X	X	
France	X	frequently	X	occasional
Germany	X	occasional	> 3 mon	
Italy	X	occasional		occasional
Netherlands	X	X	> 6 weeks	
Great Britain	X	occasional		

Table 2: Bottom ash utilization in Europe

Country	Utilization (Me= Metal recovery) (LCM = Landfill construction material)	Amounts Remaining for landfills (%)	Amounts remaining for landfills (t/a)
Austria	Me	approx. 94%	550.000
Norwegen	Me, LCM	48%	95.000
Switzerland	Me	approx. 94%	560.000
Denmark	Me, road construction, embankment	2%	15.300
France	Me, road construction	23%	707.000
Germany	Me, road construction, embankment	28%	868.000
Italy	Me, road construction, embankment, LCM	80%	603.000
Netherlands	Me, road construction, embankment	13%	150.000
USA	Me, road construction, LCM	90%	approx.15 Mio

Table 3: Amounts of bottom ash remaining for deposition in landfills in Europe (Data for Austria and Switzerland: 2011, other countries: 2005)

Pais	Empleo (DBS = en construcción de rellenos sanitarios)	Relleno sanitario %	Relleno sanitario (t/a)
Noruega	DBS	48%	95.000
Suiza	- - -	100%	600.000
Dinamarca	Carretera y construcción de presas	2%	15.300
Francia	Construcción de carreteras	23%	707.000
Alemania	Carretera y construcción de presas	28%	868.000
Italia	Carretera y construcción de presas, DBS	80%	603.000
Holanda	Carretera y construcción de presas	13%	150.000
USA	Construcción de carreteras, DBS	90%	Ca.15 Mio

Due to the presently high market prices for aluminium and copper, most of the incineration plants and bottom ash treatment plants in Europe separate Al and Cu with the aid of eddy current technique or sensor-based technique today. Typically, the process steps for bottom ash treatment and metal recovery are:

- Sieving, thereby generation 3 or 4 fractions. For example, one treatment plant in Austria sieves at 10 mm and 50 mm, another plant at 16 mm and 50 mm.
- Separation of ferrous metals (Fe) by magnets
- Subsequent separation of nonferrous metals (Al, Cu, Zn, Brass) with eddy current technique or with sensor-based technique.
- "Passive ageing": Simple storage of the metal-depleted fractions for potential further utilization in road construction

Experimental results of JAROS & HUBER, 1997 and MOSTBAUER et al, 2008 indicate that active ageing (treatment of the bottom ash with CO_2 or CO_2-containing gases) is by far more effective than passive ageing. This is in agreement with other scientific studies which were cited and reviewed by COSTA et al, 2007. Therefore, passive ageing of bottom ash is recommended by our institute since 1997.

New "BABIU" process for bottom ash utilization

The BABIU process is a special version of the active CO2 treatment of ashes. With the BABIU process (Figure 1), CO2 and H2S are removed from LFG by solid-state reactions with wet MSWI bottom ash at atmospheric pressure. Results of test runs for the BABIU system are available at a laboratory scale (each test run: approx. 70 to 80 kg bottom ash) and for bottom ashes from Austria, Germany and Italy. The CO2 uptake ranged from 10 to 39 kg/t (kg CO2 per t of wet bottom ash). The efficiency of H2S removal was larger than 98%. The larger scale (approx. 1 ton of bottom ash) of the BABIU pilot reactor at the Casa Rota landfill (Italy) and the use of real LFG instead of synthetic LFG will provide additional information in 2012.

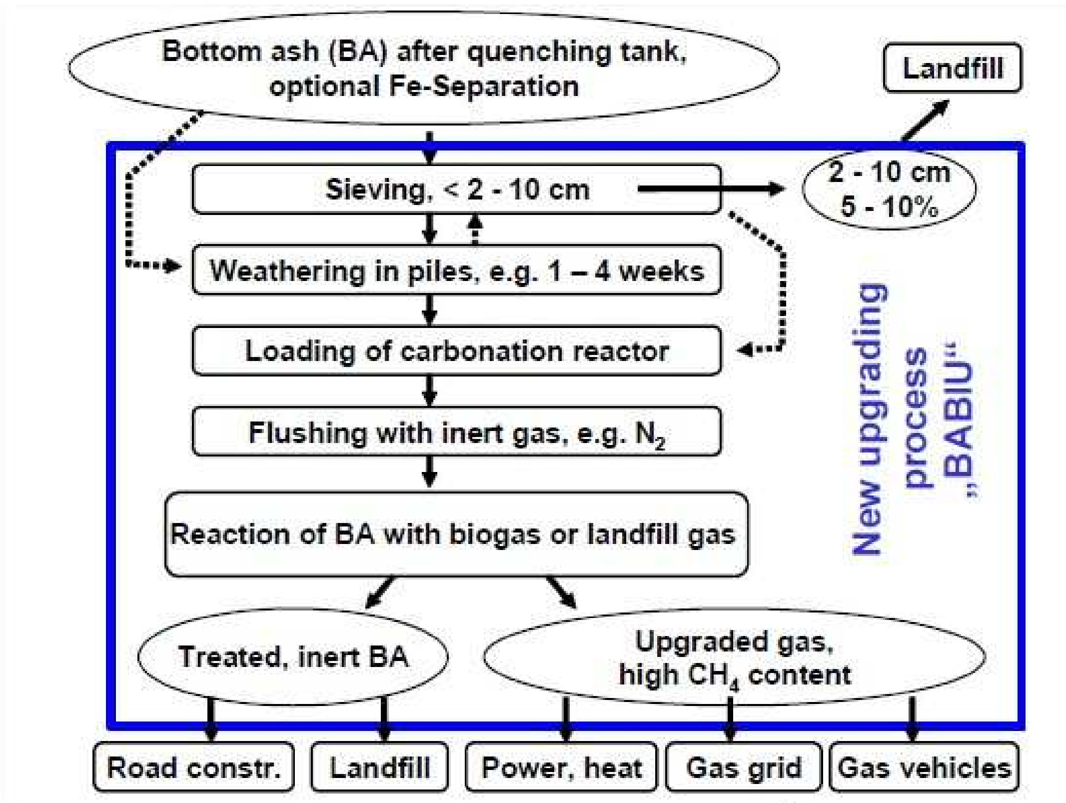

Figure 1: The BABIU process

Conclusion

Incineration residues from MSWI incineration are not an „inert material", but there are a series of reactions and environmental concerns. Active ageing of bottom ash reduces leachability and reactivity, and should be applied before landfilling or utilization. The "BABIU" process, developed at Institute of Waste Management, BOKU-University Vienna (MOSTBAUER et al, 2008), helps to reduce CO2 emissions and provides a new route for upgrading of biogas and landfill gas.

References

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