The Use of Municipal Solid Waste Incineration through the Application of Thermal Methods

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Abstract

Huge amounts of waste are being generated, and even though the incineration process reduces the mass and volume of waste to a large extent, massive amounts of residues still remain. On average, out of 1.3 billion tons of municipal solid wastes generated per year, around 130 and2.1 million tons are incinerated in the world and in Belgium, respectively. Around 400 kT of bottom ash residues are generated in Flanders, out of which only 102 kT are utilized here, and the rest is exported or landfilled due to non-conformity to environmental regulations. Landfilling makes the valuable resources in the residues unavailable and results in more primary raw materials being used, increasing mining and related hazards. Identifying and employing the right pre-treatment technique for the highest value application is the key to attaining a circular economy. We reviewed the present pre-treatment and utilization scenarios in Belgium, and the advancements in research around the world for realization of maximum utilization are reported in this paper. Uses of the material in the cement industry as a binder and cement raw meal replacement are identified as possible effect overutilization options for large quantities of bottom ash. Pre-treatment techniques that could facilitate his use are also discussed. With all the research evidence available, there is now a need for combined efforts from incineration and the cement industry for technical and economic optimization of the process flow.

Keywords: MSWI bottom ash; beneficiation; supplementary cementitious materials (SCMs); ceramics.

I. INTRODUCTION

Human life in modern societies is inevitably related to waste generation. Around 255 million tons of municipal solid waste were generated in the 27 Member-States of the European Union in 2006, an increase of 13% in comparison to 1995. This represented an average of 517 kg of municipal waste per capita, an increase of 9% over 1995. Therefore, it is not strange that waste management has become a crucial subject with increasing interest for scientists, local authorities, companies and simple citizens.

The effective management of solid waste involves the application of various treatment methods, technologies and practices. All applied technologies and systems must ensure the protection of the public health and the environment. Apart from sanitary landfill, mechanical recycling and common recycling routes for different target materials, the technologies that are applied for the management of domestic solid waste include biological treatment (composting, anaerobic digestion) and thermal treatment technologies (incineration, pyrolysis, gasification, plasma technology).

According to the New Waste Framework Directive 2008/98/EC, the waste treatment methods are categorized as "Disposal" or "Recovery" and the thermal management practices that are

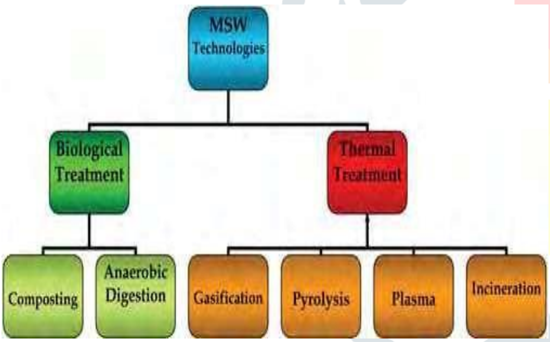

Fig. 1. Different biological and thermal methods for solid waste management

accompanied by significant energy recovery are included in the "Recovery" category. In addition, the pyramid of the priorities in the waste management sector increases.

II. INCINERATION

A. General

The incineration (combustion) of carbon-based materials in an oxygen-rich environment (greater than stoichiometric), typically at temperatures higher than 850°, produces a waste gas composed primarily of carbon dioxide (CO_2) and water (H_2O). Other air emissions are nitrogen oxides, sulphur dioxide, etc. The inorganic content of the waste is converted to ash. This is the most common and well-proven thermal process using a wide variety of fuels. During the full combustion there is oxygen in excess and, consequently, the stoichiometric coefficient of oxygen in the combustion reaction is higher than the value "1". In theory, if the coefficient is equal to "1", no carbon monoxide (CO) is produced and the average gas temperature is 1,200°C. The reactions that are then taking place are:

$$C + O_2 \rightarrow CO_2 + 93.77J \qquad (1)$$

$$CxHy + (x+ y/4)\, O_2 \rightarrow xCO_2 + y/2\, H_2O \qquad (2)$$

In the case of lack of oxygen, the reactions are characterized as incomplete combustion ones, where the produced CO_2 reacts with C that has not been consumed yet and is converted to CO at higher temperatures.

$$C + CO_2 + 172.58J \rightarrow 2CO \quad (3)$$

The object of this thermal treatment method is the reduction of the volume of the treated waste with simultaneous utilization of the contained energy. The recovered energy could be used for:

- heating
- steam production
- electric energy production

The typical amount of net energy that can be produced per ton of domestic waste is about 0.7 MWh of electricity and 2 MWh of district heating. Thus, incinerating about 600 tones of waste per day, about 17 MW of electrical power and 1,200 MWh district heating could be produced each day.

The method could be applied for the treatment of mixed solid waste as well as for the treatment of pre-selected waste. It can reduce the volume of the municipal solid waste by 90% and its weight by 75%. The incineration technology is viable for the thermal treatment of high quantities of solid waste (more than 100,000 tones per year).

A number of preconditions have to be satisfied so that the complete combustion of the treated solid waste takes place:

- adequate fuel material and oxidation means at the combustion heart
- achievable ignition temperature
- suitable mixture proportion
- continuous removal of the gases that are produced during combustion
- continuous removal of the combustion residues
- maintenance of suitable temperature within the furnace
- turbulent flow of gases

III. PYROLYSIS

Pyrolysis is the thermal degradation of carbon-based materials through the use of an indirect, external source of heat, typically at temperatures of 450 to 750°C, in the absence or almost complete absence of free oxygen. This drives off the volatile portions of the organic materials, resulting in a syngas composed primarily of H_2, CO, CO_2, CH_4 and complex hydrocarbons. The syngas can be utilized in boilers, gas turbines or internal combustion engines to generate electricity. The balance of the organic materials that are not volatile are left as char material. Inorganic materials form bottom ash that requires disposal, although some pyrolysis ash can be used for manufacturing brick materials. Pyrolysis involves the thermal degradation of organic waste in the absence of free oxygen to produce a carbonaceous char, oils and combustible gases.

Although pyrolysis is an age-old technology, its application to biomass and waste materials is a relatively recent development. An alternative term for pyrolysis is thermolysis, which is technically more accurate for biomass energy processes because these systems are usually starved-air rather than the total absence of oxygen. Although all the products of pyrolysis may be useful, the main fuel for power generation is the pyrolysis oil. Depending on the process, this oil may be used as liquid fuel for burning in a boiler or as a substitute for diesel fuel in reciprocating engines, although this normally requires further processing (Institution of Mechanical Engineers, 2007).

The reactions taking place initially are decomposition ones, where organic components of low volatility are converted into other more volatile ones:

$$CxHy \rightarrow CcHd + CmHn \quad (4)$$

Moreover, at the early stages of pyrolysis process, reactions occurring include condensation, hydrogen removal and ring formation reactions that lead to the formation of solid residue from organic substances of low volatility:

$$CxHy \rightarrow CpHq + H_2 + coke \quad (5)$$

In the case of existence of oxygen, CO and CO_2 are produced or the interaction with water is possible. The produced coke can be vaporized into O_2 and CO_2.

The pyrolysis products can be liquid, solid and gaseous. The majority of the organic substances in waste are subjected to pyrolysis by 75 – 90 % into volatile substances and by 10 – 25 % to solid residue (coke). However, due to the existence of humidity and inorganic substances, the quantity of volatile substances varies from 60 to 70% and the coke between 30 and 40%.

Solid	Carbon that is incorporated into several inert products	-
Gas	Dust particles, CO, CO_2, CH_4, H_2	700 m^3 off-gases / tone of waste
Liquid	CH_3COOH, CH_3COCH_3, CH_3OH, complex oxygenised H/C	

Table 1. Brief description of the solid, liquid and gas products from the operation of a pyrolysis unit

% v/v gas composition	Pyrolysis temperature (°C)			
	500	650	815	926
CO	33.6	30.5	34.1	35.3
CO_2	44.8	31.8	20.6	18.3
H_2	5.6	16.5	28.6	32.4
CH_4	12.5	15.9	28.6	32.4
C2H6	3.0	3.1	0.8	1.1
C2H4	0.5	2.2	2.2	2.4
Calorific Value (btu/St/t)	312	403	392	385

Table 2. Composition of the produced gas at different pyrolysis temperatures

The product proportions depend on the waste nature, the temperature conditions and the treatment time.

The products produced from pyrolysing materials are a solid residue and a synthetic gas (syngas), while some of the volatile components form tars and oils can be removed and reused. The solid residue (sometimes described as a char) is a combination of noncombustible materials and carbon. The syngas is a mixture of gases (combustible constituents include carbon monoxide, hydrogen, methane and a broad range of other VOCs). A proportion of these can be condensed to produce oils, waxes and tars. The syngas typically has a net calorific value of between 10 and 20 MJ/Nm^3. If required, the condensable fraction can be collected by cooling the syngas, potentially for use as liquid fuel (Gidarakos 2006).

IV. CONCLUSION

Thermal waste management methods should be applied together with separation at source of all materials that can be recycled in order to maximize material recovery from waste. The advantages of thermal methods in waste treatment are summarized as follows:

- Reduction of the weight and volume of the treated waste: The final solid residues have weight that varies from 3 to 20% in relation to the initial weight of waste, depending on the technology that is used. Gasification and pyrolysis result in lower quantities of solid residues comparing to incineration.
- Absence of pathogenic factors in the products:
- The products of thermal treatment, due to the high temperatures that are developed, are characterized from complete absence of pathogenic factors.
- Demand for limited areas:
- The thermal treatment units are characterized by low demands for land for their installation.

- The pyrolysis and gasification processes require less space in relation to incineration.

V. REFERENCES

Allsopp, M., Costner, P. & Johnston, P. (2001). *Incineration and human health, State of knowledge of the impacts of waste incinerators on human health*, ISBN: 90-73361-69,9, Greenpeace Research Laboratories, University of Exeter, UK

Autret, E., Berthier, F., Luszezanec, A. & Nicolas, F. (2007). Incineration of municipal and assimilated wastes in France: Assessment of latest energy and material recovery performances, *Journal of Hazardous Materials* B139, 569-574

Belgiorno, V., De Feo, G., Rocca, C. D. & Napoli, R.M.A. (2003). Energy from gasification of solid wastes, *Waste Management* 23, 1-15

Blahos, L. (2000). *Plasma Physics, the Fourth State of Matter*, Giolas Editions, 1–12

Calaminus, B. & Stahlberg, R. (1998). Continuous in-line gasification/ vitrification process for thermal waste treatment: process technology and current status of projects, Waste Management 18 (1998) 547-556