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The influence of combustion bed temperature during waste incineration on slag quality

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Abstract

The present study shows that the quality of waste incineration slag (content of heavy metals and organic carbon) cannot be improved only by increasing the combustion bed temperature. Three different incineration experiments with municipal waste were carried out with IR camera controlled combustion bed temperatures of 620–710°C, 830–911°C and 830–970°C and the slags were examined by simultaneous thermal analysis/mass spectrometry. The results of the thermal analysis of the different slags did not reveal significant differences in organic carbon content. A vaporization of heavy metal could not be observed.

Keywords: Thermal analysis/mass spectrometry; DTA; Incineration; Slag

1. Introduction

The primary aim of municipal waste incineration is the destruction of hazardous compounds within the waste or the transformation into an inert residue. At the same time the amount of waste is considerably diminished and thermal and electrical energy can be produced. Nevertheless, in general 250–350 kg of slag and 40–60 kg of boiler ash are generated from the incineration of 1 ton of waste [1].

The influence of combustion bed temperature on the quality of the waste slag has been investigated with special emphasis on heavy metals and organic carbon content. Increased combustion bed temperatures should remove heavy metals or heavy metal com-

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pounds from the slag [2] or should lead to further incorporation of these materials [3]; organic carbon should be destroyed completely.

The quality improvement of slags after incineration with increased combustion bed temperatures was investigated by means of simultaneous thermal analysis (TA)/mass spectrometry (MS).

2. Experimental

For these investigations three different municipal waste incineration experiments were carried out. By variation of firing operation parameters such as amount and distribution of air, preheating temperature, grate velocity and oxygen enrichment/depletion the combustion bed temperature was controlled.

For our investigations the firing process was driven in one case to achieve a combustion bed temperature as low as possible and in two other cases as high as possible. The combustion bed temperatures were continuously recorded by an IR camera installed in the combustion chamber of a waste incineration plant.

Combustion bed temperatures in the hottest zones in the middle of the combustion bed of 620–710°C, 830–911°C and 830–970°C were measured during these municipal waste incineration experiments.

Samples were taken every hour during the different experiments for about 8 h, leading to a total sample volume of about 100 l each. For further examination the samples were air-dried, diminished in a sample splitter and pulverized in an agate mill.

2.1. Apparatus

For the simultaneous TA/MS investigations of waste incineration slag, a TG/DTA-apparatus STA 429 from Netzsch Gerätebau GmbH coupled with a Balzers QMG 420 quadrupole mass spectrometer was used.

Experimental conditions were as follows: sample mass, 98.60 mg; atmosphere, air; heating rate, 10 K min^{-1}; crucible, Al_2O_3.

3. Results

The TG, DTG, DTA and MS results of the slags are very similar and only show insignificant differences. Typical results of waste incineration slags are shown in Fig. 1 and Tables 1–3.

The first mass loss with a DTG peak temperature of 99°C results from the evaporation of surface and crystal water. The second, quite low degradation step accompanied by an exothermic DTA effect at about 422°C probably results from the incineration of residual organic carbon.

The third mass loss in the region of 630–780°C with a DTG minimum at about 715°C probably results from calcium carbonate destruction. The related exothermic DTA maximum at about 724°C seems to be very low compared to the decomposition tempera-

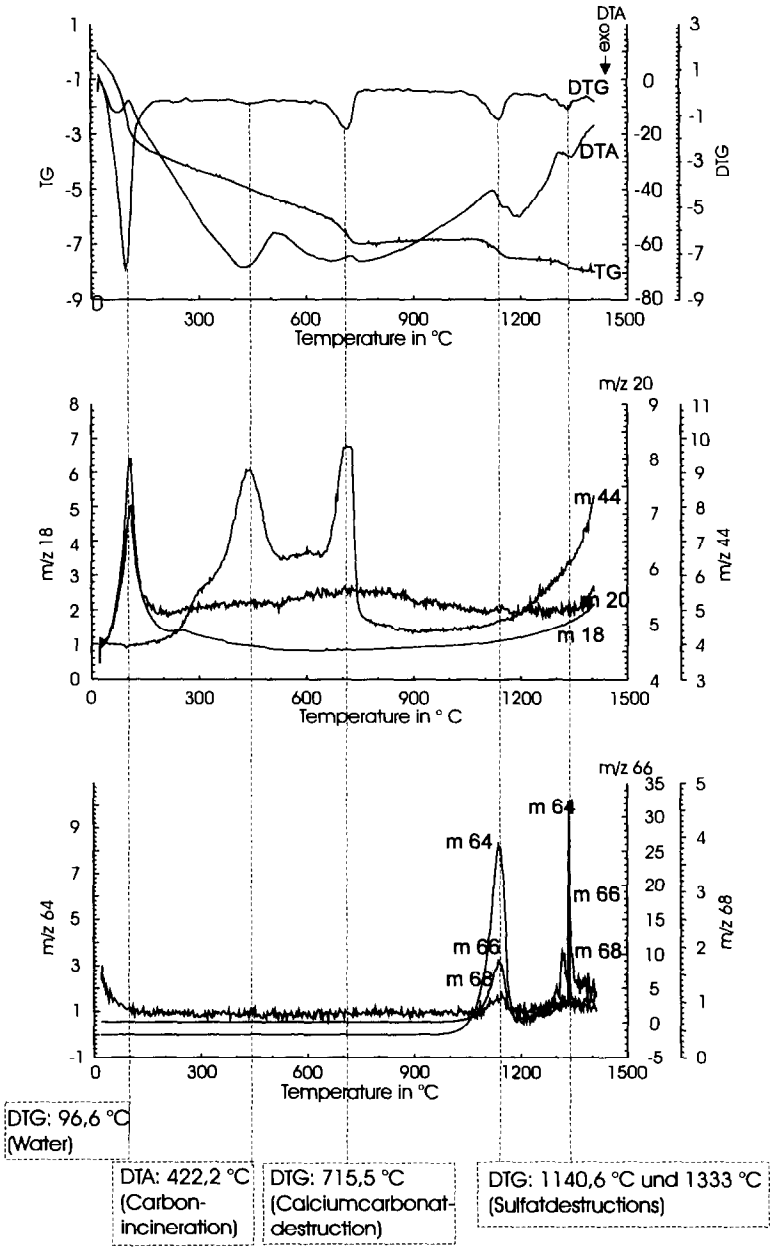

Fig. 1. Typical TA/MS results from waste incineration slag (combustion bed temperature 830–911°C). TG signal, mass change in %; DTG signal, mass change rate in % per min; DTA signal in μV. MS signals: intensity in A (different ranges) *m/z* 18:1E–7, *m/z* 20:1E–8, *m/z* 44:1E–7, *m/z* 64:1E–8, *m/z* 66:1E–9, *m/z* 68:1E–10.

Table 1
Thermal analysis data of waste incineration slag (combustion bed temperature 620–710°C)

		DTG peak /°C	TG step		Δm/%	DTA peak /°C	MS m/z
			From °C	To °C			
1	Mass loss	98.9	25.6	191.7	−4.05	100.6 (endo)	18 (H_2O)
2	Mass loss		191.7	642.1	−2.38	426.2 (exo)	44 (CO_2)
3	Mass loss	692.6	601.4	808.2	−1.00	718.8 (endo)	44 (CO_2)
4	Mass loss	1127.8	988.0	1218.2	−1.28	1127.8 (endo)	64, 66, 68 (SO_2)
5	Mass loss	1329.4	1249.2	1450.0	−0.93	1312.0 (endo)	64, 66, 68 (SO_2)

ture of calcite (898°C), but its decomposition pressure reaches about 0.1 bar at 730°C. Therefore the degradation of calcite at about 715°C can be explained by a shift of balance during thermal treatment in an open system [4].

The fourth mass loss occurs in the range 1035–1205°C with a DTG maximum at 1141°C. DTA shows an endothermic maximum at 1122°C. Due to the detection of sulphur dioxide in the MS, a degradation of sulphate compounds, probably a decomposition of calcium sulphate, can be assumed. From the degradation of calcium sulphate to calcium oxide, sulphur dioxide and oxygen (ca. 1200°C) the cleavage of sulphur dioxide can be detected at lower temperatures if the originating calcium oxide reacts with oxides of silica and alumina [4].

The last mass loss is in the region of 1239–1396°C (DTG minimum 1333°C), with an endothermic DTA effect at 1329°C again showing the cleavage of SO_2. Probably calcium sulphate, that did not react before, decomposes.

4. Discussion

The TG, DTG, DTA and MS results of the slags are similar and did not show an important influence of combustion bed temperature on the quality of slags.

Only the cleavage of water, carbon dioxide and sulphur dioxide could be detected by MS analysis. Evaporation of heavy metals and heavy metal compounds could not be

Table 2
Thermal analysis data of waste incineration slag (combustion bed temperature 830–911°C)

		DTG peak /°C	TG step		Δm/%	DTA peak /°C	MS m/z
			From °C	To °C			
1	Mass loss	96.6	25.2	189.4	−3.47	107.4 (endo)	18 (H_2O)
2	Mass loss					422.2 (exo)	44 (CO_2)
3	Mass loss	715.5	630.6	783.1	−1.07	724.3 (endo)	44 (CO_2)
4	Mass loss	1140.6	1035.4	1205.1	−0.69	1121.7 (endo)	64, 66, 68 (SO_2)
5	Mass loss	1333.2	1239.2	1396.9	−0.36	1329.4 (endo)	64, 66, 68 (SO_2)

Table 3
Thermal analysis data of waste incineration slag (combustion bed temperature 830–970°C)

		DTG peak /°C	TG step		Δm/%	DTA peak /°C	MS m/z
			From °C	To °C			
1	Mass loss	93.5	25.3	131.4	−1.14	97.2 (endo)	18 (H_2O)
2	Mass loss		129.2	604.8	−1.25	449.7 (exo)	44 (CO_2)
3	Mass loss	684.5	607.8	728.9	−0.55	44 (CO_2)	
4	Mass loss	1099.3	1028.0	1179.5	−0.24	1144.0 (endo)	64, 66, 68 (SO_2)
5	Mass loss	1362.9	1182.1	1405.9	−0.49		64, 66, 68 (SO_2)

demonstrated. Due to the very low concentration of heavy metals in the slags, DTA/DTG peaks were not to be expected. The missing proof of heavy metals within the sensitive MS, is most probably not a result of absent vaporization of heavy metals or heavy metal compounds, but is due to the orifice system used and the buildup of oxygen compounds. During a similar TA analysis with boiler ashes [4] in high vacuum, without use of the orifice system, Zn and Pb compounds could be detected by MS. The proof of elementary Zn in MS is disturbed by SO_2.

In this case, measurements under high vacuum were not performed, because they have less in common with real combustion conditions in a waste incineration plant.

The combustion bed temperatures measured during the different experiments were in a maximum range from 620 to 970°C. Within this temperature region the different slags examined only showed decomposition of calcium carbonate. Evaporation of crystal and surface water and incineration of organic carbon are finished at temperatures below 600°C; decomposition of sulphate compounds did not start at temperatures below 1000°C. From this, the TA results did not show significant improvement of slag quality by increasing combustion bed temperature during waste incineration in the temperature range examined. The relatively high amount of residual organic carbon in the slags did show that outburn of the slags is not optimal and has to be improved. This improvement can not be attained only by increasing the combustion bed temperature, but also requires a more equal burning within the combustion chamber.

Combustion bed temperature will only have an important influence on the quality of the slag when the melting point (ca. 1200°C) is exceeded. From the molten slag, a glassy matrix, which immobilizes heavy metals and other toxic compounds [5,6], can be achieved.

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