Chapter 6

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Adverse Environmental Impact Caused by Thermal Destruction of Animal By-Products

1. Introduction

Scientific and technological advancement has led to minimisation of adverse environmental impact caused by thermal processing of waste, while resulting in the introduction of a large number of pro-ecological changes in standard waste incineration technologies. Among the classic methods for waste management, including animal carcass disposal is the production of meat and bone meals based primarily on Hartmann pressure sterilisation system or its modifications carried out in specialised waste management facilities. Introduction of thermal disposal technology and limits on meat and bone meal feeding have forced the use of alternative waste management methods. Small-size incineration plants intended for thermal destruction of animal waste can be used in large pig and poultry breeding farms, slaughterhouses, meat processing plants, fur farms, larger veterinary centres or animal carcass incineration plants. This method enables one to avoid long-term storage of animal mortality which might be a nuisance when using central collection points or large waste management facilities. Furthermore, it limits transport of sick animals reducing the spreading of diseases. Literature on the subject describing current procedures and technologies of animal by-products incineration in small incineration plants with a capacity up to 1 ton per hour contains few data on the actual adverse environmental impact caused by these types of waste management processes.

2. Test conditions

This article presents results of exhaust emission measurements conducted in four animal carcass incineration systems with a capacity of 400 and 500 kg/h operating in the UK, as well as analysing ash remains from one of the above systems. Data on exhaust emission and protein in ash from the system 2 were

obtained by courtesy of Todaysure Project Ltd. Ash sample from the system 3 was analysed in the Elementary Analyses and Environmental Research Laboratory, Department of Environmental Chemistry, University of Technology and Life Sciences in Bydgoszcz. Measurements were made in the years 2004-2009. The three incinerators have the form of a kiln with a fixed incineration chamber with one of the chambers having a rotary kiln. The rotary kiln moves on four rolls seated on a special frame and is driven by the chain transmission enabling control of revolutions within a range of 2-10 revolutions per minute. Figure 1 shows a rotary kiln system – system 3 as per Table 1.

Fig. 1. Animal carcass thermal destruction system with a rotary kiln, capacity: 500 kg/hour (courtesy of Todaysure Project Ltd)

Due to the special structure of combustion chambers, incineration process is carried out under optimal conditions and exhaust gases have a low content of harmful substances. It is mainly animal carcass and animal by-products that are disposed of. Waste is put inside incineration chambers laid on the inside with insulation or special concrete mass. Required process temperatures are maintained by oil-fed fan burners fitted in the chamber walls. In order to ensure correct oxidation, the chambers are equipped with additional air supply systems. The system for measuring and controlling oxygen in exhausts ensures the most optimal flow of each process stage, including full-load operation, start-up or stop. The resulting gas products are sent to aftercombustion chambers where, at a preset

high temperature, organic substances are destroyed by heating and oxidized to obtain final combustion products. Chamber dimensions ensure exhaust residence time of above 2 sec at a temperature of above 850°C. This causes contaminant level in outgoing exhaust to drop. The aftercombustion chambers have the shape of steel rectangular prisms and are laid on the inside with special concrete mass separated from the external lining with an insulation layer. Hot outgoing exhausts are vented gravitationally from aftercombustion chambers to the atmosphere through the vertical flue. The temperature inside an aftercombustion chamber is controlled automatically by means of a variable capacity oil burner. Oxygen concentration in exhaust is controlled and maintained automatically at the minimum desired level of 6%. The kilns are equipped with in-situ exhaust emission continuous measurement devices used for measuring oxygen, carbon monoxide and dust content as well as temperature and exhaust flow levels. The results presented in the article were obtained from measurements carried out as part of periodic control tests conducted by an accredited laboratory. Measurements were made within the round ceramic exhaust duct. No additional air for dispersing or cooling exhaust gases was supplied in front of the measuring point. The systems were not equipped with additional exhaust cleaning systems. At the time when the measurements were made, the systems were subject to the following regulations: Pollution Prevention and Control Act 1999, Pollution Prevention & Control Regulations 2000 and The Process Guidance Note (PG) 5/3(04) „Secretary of State's Guidance – Animal Remains Incineration Processes under 1 tonne an hour” Discussed installations are presented in Table 1.

Table 1

Waste incineration installations

Facility no.	Installation description	Emission measurement date	Capacity kg/h
1	Fixed combustion chamber, direct feed, aftercombustion chamber	February 2004	500
2	Fixed combustion chamber, direct feed, aftercombustion chamber	July 2009	500
3	Rotary combustion chamber, feed by milled waste pump, aftercombustion chamber	April 2008	500
4	Direct feed, fixed combustion chamber, aftercombustion chamber	February 2006	400

3. Test results

Test methodology. Test methods comprising hydrogen chloride (HCl), oxides of sulphur (SO_2), moisture, carbon monoxide (CO), oxygen (O_2), total particulate matter (TPM), sulphur dioxide (SO_2) and total organic carbon (VOCs) as well as standards concerning performance of these measurements are given in Table 2.

Table 2

Test scope and methods used in gas emission measurements

Determinant	Source Document	Other Details (Analysys. Duration, no. of tests, equipment)
Hydrogen chloride (HCl)	BS-EN1911:1998	Absorption in deionised water and analysis for chloride by ion chromatography.
Oxides of sulphur (SO_2)	ISO 11632	Absorptionin 3% Hydrogen peroxide and analysis for sulfate by ion chromatography.
Moisture	USEPA4 (modified)	Condensation and absorption on silica gel followed by gravimetric analysis.
Carbon monoxide (CO)	BS-EN15058	On-Line Infra-red analysis.
Oxygen (O_2)	ISO 12039	On-line analysis using paramagnetism.
Total particulate matter (TPM)	ISO 9096	Single point isokinectic sampling for length of batch followed by gravimetric analysis.
Sulphur dioxide (SO_2)	ISO 7935	On-Line Infra-red analysis.
Total organic carbon (VOCs)	BS-EN13526	On-Line analysis by flame ionization detection.

Exhaust flue dust sampling was performed using APEX respiratory equipment based on USEPA Method 5 recommendations concerning isokinetic measurement equipment and requirements of BS 9096:2003 standard. The weight of filtered solid particles was used to determine concentration of particles within the sample taken. Gas velocity was measured by means of the Pitot tube, while the temperature using thermocouple.

Gravimetric analysis was performed with an accuracy of ± 0.1 mg (N) m^{-3}. Hydrogen chloride HCl content measurements were performed in accordance with BS-EN1911:1998. Taken samples were analysed using ion chromatography method. Volatile organic compounds (VOCs) were determined in accordance with BS-EN13526 using flame ionization detector (FID). The measured values of volatile organic compounds were expressed as total carbon. Carbon monoxide was measured using NDIR method in accordance with BS-EN15058. Oxygen concentration was measured with a zirconia probe. To perform quantitative and qualitative determination of solid remains following thermal destruction of waste, including calcium (Ca), phosphorus (P), magnesium (Mg), sulphur (S) and carbon (C) compounds as well as silicone dioxide (SiO_2), instrumental methods were used: spectroscopy within UV-VIS range using Perkin-Elmer UV-VIS Lambda 20 spectrometer, flame ionization detector with a Primacs TOC analyser manufactured by Skalar (Breda) as well as other reference methods.

4. Results and discussion

Measurement results are shown in the tables below. Gas emission concentration levels were referred to normal conditions defined in accordance with the Regulation by the Minister of the Environment dated 22 April 2011 on standards concerning emissions from installations (Journal of Laws 2011 no. 95, item 558): temperature – 273 K, pressure – 101.3 kPa, oxygen content – 11% under dry gas conditions. Substance concentration in waste gases was expressed in milligrams of substance per cubic meter of waste gases referred to agreed conditions determined as $mg.(N)m^{-3}$. Substance concentration in waste gases was presented for standard content of oxygen in waste gases and calculated according to the following formula (1):

$$E_1 = \frac{21 - O_1}{21 - O_2} x E_2 \qquad \text{formula (1)}$$

where: E_1 – means substance concentration in waste gases for standard oxygen content in waste gases,
E_2 – means substance concentration in waste gases (measured or calculated),
O_1 – means standard oxygen content in waste gases expressed in percents,
O_8 – means oxygen content in waste gases expressed in percents.

Gas emission test results were obtained from measuring weights of respective components. Concentration under reference conditions was calculated and measurement errors determined with a 95% confidence interval. To illustrate emission parameters, table 3 presents physical values of exhaust such as temperature, exhaust flow velocity, oxygen content in exhaust gases and moisture content. Measurement cross-section diameter was provided in all cases.

Table 3

Emission parameters for animal carcass incineration installation (courtesy of Todaysure Project Ltd.)

Parameter	Average			
	Installation 1	Installation 2	Installation 3	Installation 4
Temperature (^oC)	794.0	887.0	731.0	706.1
Linear gas Velocity ($m.s^{-1}$)	6.76	14.44	9.29	10.08
Volumetric Flow Rate ($m3.h^{-1}$)	3454.55	6147.82	4256.37	4591,1
Oxygen (%)	12.30	13.24	9.8	13.64
Moisture (%)	9.73	10.37	13.3	6.95
Internal Stack Dimensions (m)	0.84	0.84	0.77	0.76

Table 4

Pollution concentration measurements for installation 1 (courtesy of Todaysure Project Ltd.)

Pollutant	Mass Emission Rate (gs^{-1})	Concentration at: 273K, 101.3 kPa, 11% O_2, dry gas ($mg(N)m^{-3}$)	Estimate of uncertainty (2σ at 95% confidence)
TMP	0.0548	72.2	11.28%
VOC	0.0040	4.65	8.6%
Carbon Monoxide	0.0089	11.86	8.86%
Hydrogen Chloride	0.0019	2.27	8.6%
Sulphur Dioxide	0.0510	67.81	8.86%

Table 5

Pollution concentration measurements for installation 2 (courtesy of Todaysure Project Ltd.)

Pollutant	Mass Emission Rate (gs^{-1})	Concentration at: 273K, 101.3 kPa, 11% O_2, dry gas ($mg(N)m^{-3}$)	Estimate of uncertainty (2σ at 95% confidence)
TMP	0.1070	90.2	+/- 49%
VOC	0.0122	9.77	+/- 10%
Carbon Monoxide	0.1086	87.2	+/- 10%
Hydrogen Chloride	0.0425	35.9	+/- 7%
Sulphur Dioxide	0.2498	210.7	+/- 8%

Table 6

Pollution concentration measurements for installation 3 (courtesy of Todaysure Project Ltd.)

Pollutant	Mass Emission Rate (gs^{-1})	Concentration at: 273K, 101.3 kPa, 11% O_2, dry gas ($mg(N)m^{-3}$)	Estimate of uncertainty (2σ at 95% confidence)
TMP	0.0940	78.49	+/- 12
VOC	0.0039	3.38	+/- 2
Carbon Monoxide	0.0145	12.75	+/- 5
Hydrogen Chloride	0.0707	67.0	+/- 4
Sulphur Dioxide	0.2234	212.7	+/- 17

Table 7

Results of pollution concentration measurements for installation 4 (courtesy of Todaysure Project Ltd.)

Pollutant	Mass Emission Rate (gs^{-1})	Concentration at: 273K, 101.3 kPa, 11% O_2, dry gas ($mg(N)m^{-3}$)	Estimate of uncertainty (2σ at 95% confidence)
TMP	0.0693	79.5	+/- 13 %
VOC	0.0039	4.46	+/-15 %
Carbon Monoxide	0.0221	25.4	+/- 15 %
Hydrogen Chloride	0.0182	20.9	+/- 11 %
Sulphur Dioxide	0.0685	78.5	+/- 15 %

Values of gas pollution concentration level measurements results in reference to limit values specified in Referencing Federal EPA 40 CFR 60, Appendix A, Method 5 – „Determination of Particulate Emissions from Stationary Sources” are shown in table 8.

Table 8

Results of gas pollution emission measurements with reference to limit values

Pollutant	Installation without a flue gas cleaning systems				Part B Benchmarkt (as given in Process Guidance Notes) for animal remains
	Concentration ($mg \cdot m^{-3}$)				
	1	2	3	4	
Particulate matter(TPM)	72.2	90.2	78.49	79.5	100
Volatile organic compounds as carbon	4.65	9.77	3.38	4.46	20
Carbon monoxide (CO)	2.27	87.2	12.75	25.4	100
Hydrogen chloride (HCl)	11.86	35.9	67.0	78.5	100
Sulfur dioxide (SO_2)	67.81	210.7	212.7	20.9	300

As part of the environmental impact assessment, ash samples from installation 3 were taken. Analysis results were obtained as shown in Table 9.

Table 9

Ash chemical composition measurement results for installation 3 (by courtesy of the Elementary Analyses and Environmental Research Laboratory, Department of Environmental Chemistry, University of Technology and Life Sciences in Bydgoszcz)

Feature name	Unit	Result
pH reaction in H_2O	pH	8.24
Dry mass content	%	97.8
Organic matter content	% dry mass	0.68
Total carbon content (C_t)	% dry mass	0.41
Total nitrogen content (N)	% dry mass	0.17
Total phosphorus content (P)	% dry mass	6,07
Calcium content (Ca)	% dry mass	13.52
Magnesium content (Mg)	% dry mass	0.58
Cadmium content (Cd)	mg .kg^{-1}of dry mass	1.34
Lead content (Pb)	mg .kg^{-1}of dry mass	8.66
Mercury content (Hg)	mg .kg^{-1}of dry mass	Not found
Zink content (Zn)	mg .kg^{-1}of dry mass	16.3
Copper content (Cu)	mg .kg^{-1}of dry mass	3.61
Chromium content (Cr)	mg .kg^{-1}of dry mass	5.28
Nickel (Ni)	mg .kg^{-1}of dry mass	2.11

To assess correctness of incineration process in installation 2, solid process remains were analysed for presence of organic substances in ash. Results of the analysis conducted by an accredited laboratory are presented in Table 10.

Table 10

Results of protein content in ash sample measurements – installation 3 (by courtesy of firmy Todaysure Project Ltd.)

Amino Acid	mg protein/100g sample
ASPARTIC ACID	0,05
GLUTAMIC ACID	ND <0.018
SERINE	0,04
GLYCINE	0,08
HISTIDINE	ND <0.011
ARGININE	Trace <0.113

Table 10 continued

Amino Acid	mg protein/100g sample
THREONINE	ND <0.021
ALANINE	Trace <0.029
PROLINE	Trace <0.009
TYROSINE	0,04
VALINE	Trace <0.016
METHIONINE	0,32
ISOLEUCINE	Trace <0.011
LEUCINE	0,02
PHENYLALANINE	0,07
LYSINE	Trace <0.047
Total	0,61
Organic Carbon	0.14% m/m

5. Summary and conclusions

The aim of the tests was to assess environmental impact of animal carcass disposal systems, in particular emission of pollutants to the atmosphere, and analyse thermal disposal efficiency expressed as maximum content of non-oxidized organic compounds determined by the content of total organic carbon. The tests have shown that animal carcass incineration requirements related to gas pollution emission are met even though the installations were not equipped with additional exhaust cleaning systems except for exhaust gas after combustion chambers. Although emission standards for animal carcass incinerator systems are not specified, it is possible to reduce emission considerably, in particular the level of volatile organic compounds, carbon monoxide and dust, with the use of additional exhaust cleaning systems. Emissions of these substances are an indicator of incineration efficiency. It is also possible to reduce emission of such gases as hydrogen chloride and sulphur dioxide by adding neutralizing agents. Once emission standards are met and available energy recovery methods utilised, it is appropriate to consider potential benefits brought by the use of local animal waste disposal installations in the context of efficient combating of diseases, storage and transport of waste as well as the environmental impact of vehicles carrying such waste. As far as fertilizing value of remains following thermal disposal is concerned, obtained material may be a source of phosphorus, nitrogen, calcium, magnesium and microelements. Comparatively high content of total phosphorus – 6.07% dry mass, calcium 13.52%, magnesium 0.58% and total

nitrogen – 0.17% makes it suitable for use in the production of fertilizers and plant growth enhancers. Heavy metals content in solid process remains is much lower than permissible values for mineral fertilizers available on the market.

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