ATMOSPHERIC EMISSIONS FROM SMALL CARCASS INCINERATORS

A report produced for the Department for Environment, Food and Rural Affairs

By AEA Technology Environment

August 2002

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AEA Technology Environment
Culham Science Centre
Abingdon
Oxfordshire
OX14 3ED

Telephone +44 1235 463863
Facsimile +44 1235 463038

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	Name	Signature	Date
Approved by	Dr Alan Collings Technical Manager		

Authors

Emission monitoring team

A. Collings
M. Davies
B. Donovan
R. Glass
P. McConaghy
R. Stewart
D. Taylor

Analysis of data and report writing

R. Stewart
A. Collings
H. H. Jones
C. Handley
M. Holland

Executive Summary

AEA Technology Environment have been contracted by the Department for Environment, Food and Rural Affairs (DEFRA) to measure and review emissions to air from small-scale animal carcass incinerators[1]. The study has been designed to inform government as progress is made regarding amendment of the Animal Waste Directive (90/667/EEC).

There are about 2,600 such incinerators in the UK, located at sites such as farms, rendering plant, pet crematoria, hunt kennels and some veterinary practices. The specific objectives of the study were:

- To measure emissions from such incinerators
- To identify options for improvements
- To make recommendations on best available techniques.

A comprehensive search of both published and unpublished literature was conducted to determine current practices and technology for the incineration of animal carcasses in small incinerators and to determine information available on the emissions from such incinerators.

A representative set of eleven sites was selected following discussion with stakeholders. The incinerators selected varied with respect to factors including manufacturer, age, specification (critically, with or without afterburners), feedstock and maintenance. A test protocol was developed to determine emissions of eight pollutants (SO_2, HCl, NO_x, TPM, CO, CO_2, dioxins/furans and VOCs) using reference test methods.

The impact on air quality was assessed on both a national and local scale in terms of contribution to total UK emissions and local pollutant concentration. Two scenarios were then considered as alternatives to the current on-farm incineration to establish potential improvements that could be made. The alternatives considered were:

- Diverting waste to a central incineration facility and
- Replacing the current UK small incinerator mix with the least polluting model.

RESULTS

Literature Review

The literature survey suggests that although small animal carcass incinerators are used in other countries in Europe and in the USA. The UK

[1] Defined as those with a maximum input of animal material for disposal of less than 50 kg/hr.

usage appears to be far more intensive and subject to less regulation than elsewhere in Europe although this situation will change with the introduction of the EU Animal By-Products Regulation which will harmonise regulatory controls on small carcass incinerators across Europe. The environmental performance of these machines is not well known. Furthermore the scale of use of small carcass incinerators in UK clearly illustrates the need for emission data to enable informed policy formulation.

Emission test data

Results for individual incinerators are summarised in Table A1. It was observed that the presence of afterburners made a major difference to emission of some pollutants, so results are grouped according to presence or absence of this technology. The ages of the plant range from five months to six years, with a median age of twelve months.

Table A1 - Incinerator emissions monitored at each site with summary data

Site	Location	Fuel	TPM	SO_2	HCl	CO	NO_x	VOCs	Dioxins & furans	CO_2
			$mg.m^{-3}$	$mg.m^{-3}$	$mg.m^{-3}$	$mg.m^{-3}$	$mg.m^{-3}$ (as NO_2)	$mg.m^{-3}$ (as C)	$ngITEQ.m^{-3}$	%
Incinerators with afterburners										
1	Abattoir	Propane	27	77	39	4.2	614	1	0.06	7.3
3	Pet crematorium	Heating oil	106	190	23	150	234	23	0.40	8.1
4	Poultry farm	Propane	58	179	58	1030	381	61	0.19	7.2
7	Poultry farm	Propane	68	169	24	3990	236	322	0.07	7.0
8	Farm	Red diesel	749	265	9	6310	247	10000	0.14	6.8
9	Pig farm	Diesel	36	376	24	1650	376	117	0.10	7.6
10	Poultry farm	Propane	90	34	8	1620	303	484	0.10	6.9
11	Hunt kennels	Propane	373	164	60	1760	230	1170	0.23	6.9
	Minimum		*27*	*34*	*8*	*4*	*234*	*1*	*0.06*	*6.8*
	Maximum		*749*	*376*	*58*	*6310*	*614*	*10000*	*0.40*	*8.1*
	Average		*188*	*181*	*30*	*2063*	*327*	*1523*	*0.16*	*7.2*
Incinerators without afterburners										
2	Poultry farm	Kerosene	107	456	112	348	225	869	0.08	7.7
5	Pig farm	Gas oil	173	127	26	1180	129	78	0.21	7.5
6	Pig farm	Oil	277	313	56	5840	352	3490	0.05	9.0
	Minimum		*107*	*127*	*26*	*348*	*129*	*78*	*0.05*	*7.5*
	Maximum		*277*	*456*	*112*	*5840*	*352*	*3490*	*0.21*	*9.0*
	Average		*186*	*284*	*65*	*2453*	*235*	*1480*	*0.11*	*8.1*
All sites										
	Minimum		27	34	8	4	129	1	0.05	6.8
	Maximum		749	456	112	6310	614	10000	0.40	9.0
	Average		187	213	40	2170	302	1510	0.15	7.7

Concentrations are standardised to mass concentrations at 11% O_2, dry and STP (0°C, 101.3 kPa) which is the normal standardisation condition for waste combustion processes.

The contribution of small carcass incinerators to total UK emissions and total emissions from agriculture activities is summarised in Table A2.

Table A2 - Contribution of incineration to total United Kingdom emissions of key pollutants in 1999

Source (SNAP sector)	PM_{10} (kt)	SO_2 (kt)	HCl (kt)	CO (kt)	NOx (kt) (as NO_2)	VOC (kt) (as C)	Dioxin gITEQ	CO_2 (kt) (as C)
Estimated total UK emissions from Small–scale carcass incinerators								
Small carcass incinerators	0.31[note 2]	0.33	0.07	3.3	0.49	2.0	0.25	65
Small–scale carcass incinerators contribution to agriculture total (%)								
	1.6[note 2]	7.5	>100	14	1.8	35	3.2	7.1
Small–scale carcass incinerators contribution total national emissions (%)								
	0.17[note 2]	*0.03*	*0.07*	*0.07*	*0.03*	*0.11*	*0.07*	*0.04*

Note 1 The NAEI Agriculture, forestry and land use source sector does not include emissions from process plant and off road vehicles (for example). The total figures for agriculture include emission contributions from the Agriculture, Other transport and Combustion sectors.
Note 2 Figures provided are for total particulate matter and therefore may overestimate of PM10 emissions and contribution.

The results from this study demonstrate that the contribution of emissions from small carcass incinerators to the national total is very low at or less than 0.2% for all the measured pollutants.

Evaluation of Best Available Techniques

The likely costs of the scenarios have not been considered as this was outwith the scope of work. In addition, several animal health issues (for example the implication of poor combustion and the potential for spreading disease through vehicle movement) have been identified. The BAT review in this report does not include a risk assessment of these issues.

The evaluation indicates that significant reductions in emissions to atmosphere are achievable with an optimised small incinerator. Although the improvements in HCl or SO_2 acid gas emissions would not match those achievable with a larger facility and overall NO_x emissions would be higher. Nonetheless, the reductions in other emissions would be similar to those indicated for the large central facility. This evaluation indicates that the use of an on-site incinerator with afterburner can be considered to represent BAT for animal remains disposal.

Use of large central incineration facilities would allow supervision through existing an regulatory framework. The continued use of small on-site incinerators would require development of a type approval scheme or other supervision measures.

Upgrading or renewal of the incinerator population to match the best achievable in this survey is part of the recommendation on of BAT. However, BAT should also include other technical and management improvements.

CONCLUSIONS

Significant reductions in emissions to atmosphere are achievable with an optimised small incinerator. Although the improvements in HCl or SO_2 emissions would not match those achievable with a larger facility and overall NO_x emissions would increase. Nonetheless, the reductions in other emissions would be similar to those indicated for the large facility. This evaluation indicates that the use of an on-site incinerator with afterburner can be considered to represent BAT for animal remains disposal.

The BAT review also includes recommendations on furnace design, operation and management. Improvements are indicated in housekeeping, storage and handling of animal remains, fuels use and storage, residue disposal, operating temperature, loading and, operator training.

A type approval system for incinerators is recommended to minimise the opportunity for installation of more polluting designs.

Training of operators is recommended and only fully trained individuals should be permitted to operate the incinerators.

At the hunts and abattoirs (where carcasses were being butchered to provide meat for animal or human consumption), use of an on-site incinerator to burn the waste can be considered as a natural extension to the operator’s activities. At other sites, the standard of housekeeping varied a great deal and operation and supervision of the incinerator was similarly variable.

Plant fitted with afterburners general produce less emissions, with the exception of oxides of nitrogen, than incinerators without afterburners.

Several of the incinerators perform well against the benchmark releases provided in current guidance for animal remains incinerators prescribed for local authority air pollution control.

Dioxin emission concentrations surveyed were less than 1 ng(ITEQ).m^{-3}. with several incinerators meeting the Waste Incineration Directive limit of 0.1 ng.ITEQ.m^{-3}.

The results from this study demonstrate that the contribution of emissions from small carcass incinerators to the UK national total is very low at (or less than) 0.2% for all the measured pollutants.

For all pollutants given NAQS targets, a small carcass incinerator would typically contribute less than 0.5% to the each of the total pollutant concentration limits in the area outside a 1km radius of the incinerator.

Where diseased animal carcasses are being incinerated, poor combustion may not completely destroy the diseased material and the resulting particle emissions could provide a transport mechanism for disease, and potentially prions, to other animals in the surrounding area via direct inhalation or ingestion of material deposited on to pasture.

Alternatives to on-farm incineration, involving collection of material for disposal at a larger centralised site, may cause problems through the spread of disease from farm to farm.

AEA Technology Environment recommends that a risk assessment is undertaken to ensure that the final choice of disposal methods for animal remains addresses both environmental and animal health issues.

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1 Introduction

The Department for Environment, Food and Rural Affairs (DEFRA) contracted AEA Technology Environment to undertake a review of emissions to air from small-scale animal carcass incinerators. These are defined as having a maximum throughput of animal remains of up to 50 kg/hr and are exempted from regulation under the Waste Incineration Directive (2000/76/EC) as they will be covered under an amendment to the Animal Waste Directive (90/667/EEC). In addition to quantifying the air pollution arising from these incinerators this review identifies options for improvements in order to inform the United Kingdom Government's negotiations on the content of the amended Directive.

Small-scale incinerators are used at a variety of sites, including:

- Farms (particularly those with pigs and poultry)
- Abattoirs
- Meat processing plant
- Hunt kennels
- Larger veterinary practices
- Pet crematoria

On-site combustion of animal remains offers a number of advantages. It provides an effective means of disposing of potentially harmful material when carried out to a high standard. It avoids the need for prolonged storage of animals after death, which could be problematic were farmers (and other operators) to use a central collection/combustion facility. It also reduces the need for movement of possibly diseased remains, and hence may facilitate disease control.

Against these advantages there are also some problems. The design and use of these incinerators are largely unregulated. There is currently no need for operatives to be trained in their use and hygiene/housekeeping standards vary enormously between sites. As discussed in this report, these factors make a substantial difference to the environmental performance of small incinerators.

The study progressed through four distinct phases, as shown in Figure 1. Further details are provided in the following sections.

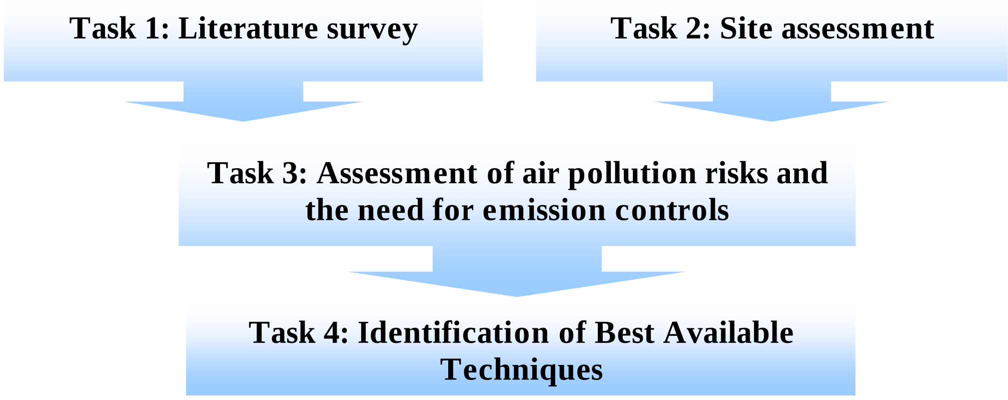

Figure 1 Outline of study methodology

2 Methodology

2.1 LITERATURE REVIEW

A comprehensive search of both published and unpublished literature was conducted to determine current practices and technology for the incineration of animal carcasses in small incinerators and to determine information available on the emissions from such incinerators.

The starting point for this review was to contact the incinerator manufacturers [ADAS (2001)] in order to identify available information on the performance and emissions from these incinerators. An extensive database and web search was also undertaken in order to identify work or articles about similar incineration facilities across Europe. The authors also drew on personal contacts in Europe.

Details of the organisations contacted and the outcomes of these contacts are provided in Appendix A.

2.2 SITE ASSESSMENTS

2.2.1 Initial site selection

Each incinerator manufacturer listed by ADAS was contacted in order to identify sites using animal carcass incinerators. A telephone survey of sites was subsequently carried out to identify 14 sites for visual assessment. The sites were selected on the basis of providing a representative cross-section of installed equipment and feed stock.

The next step in the site selection process was to carry out reconnaissance visits of selected sites with a view to finding up to 11 suitable incinerators for monitoring. The objectives of these visits were to:

- Undertake an initial site appraisal to ascertain any site sensitivities and the state of the incinerator;
- To inform the measurement teams of the logistical and safety aspects of the sampling exercise including any modifications required to facilitate measurements; and
- To brief the site operator on the purpose of the study.

Following the reconnaissance visits, suitable sites were then selected for measurement.

2.2.2 Measurement protocol

Protocol development - A protocol to measure emissions from the animal carcass incinerators was developed from reference test methods used for assessing emissions from industrial processes.

Initially a desk study was conducted to work through what parameters were required to be tested and possible solutions were found. However, this had to be put into practice. A protocol development site was selected from the sites identified in the site assessment exercise. A measurement team comprising two experience team leaders visited the site with sets of test equipment in order to address the practicalities of sampling from such small processes.

During this work programme the team worked through a number of possible ways of testing on a ‘live’ incinerator and developed a set of procedures that would:

- Ensure reliable results from each of the sites, with minimum deviation from standard methods.
- Produce a safe system of work bearing in mind the operating temperatures of these incinerators and the other hazards that can be expected on a working farm.

Sampling methods - Table 1 summaries our test protocols. Further details of the test procedures can be found in Appendix B.

When sampling for particulate and dioxins/furans measurement it is best practice to employ a multipoint, isokinetic sampling strategy because variation in particle size and particulate concentrations across a sampling plane can be significant. All reference test methods for particulate (or for materials with a particulate fraction) employ a multipoint, isokinetic sampling strategy. Although the reference test method adopted for particulate and dioxins/furans allows single point sampling at small ducts (diameters <0.35m) it can lead to high uncertainty (>10%).

However, due to the limited space at these small incinerators it was considered impractical to use a multipoint sampling for the dioxin/furan and particulate tests. In addition, unlike continuous processes, the emissions were expected to vary with time. The degree of variation in concentration across the sampling plane was not expected to be as significant as the variation in concentration over the duration of the burn. Hence, single point sampling was used.

Table 1 Summary of test protocols

Determinant and netcen Work Instruction		Source Document	Other Details (Analysis. Duration, no. of tests, equipment)	UKAS Accreditation	
				Sampling	Analysis
Hydrogen chloride (HCl)	100	EN 1911 (modified)	Absorption in deionised water and analysis for chloride by ion chromatography. Approx. 2 to 3*2h tests (over batch).	Yes	Yes
Oxides of sulfur (SO_2)	100	ISO 11632	Absorption in 3% Hydrogen peroxide and analysis for sulfate by ion chromatography Approx. 2 to 3*2h tests (over batch).	Yes	Yes
Dioxin and furans	105	EN 1948 (modified)	Single point isokinetic sampling for length of batch with multi-component analysis for 2,3,7,8 isomers using HRGC HRMS.	Yes	Yes
Moisture	115	USEPA 4 (modified)	Condensation and absorption on silica gel followed by gravimetric analysis. Two tests per test day as a minimum.	Yes	Yes
Carbon monoxide (CO)	116	ISO 12039	On-Line Infra-red analysis for whole of test day.	Yes	Yes
Oxygen (O_2)	117	ISO 12039	On-Line analysis using paramagnetism. Throughout all tests.	Yes	Yes
Total particulate matter (TPM)	118	ISO 9096	Single point isokinetic sampling for length of batch followed by gravimetric analysis.	Yes	Yes
Sulfur dioxide (SO_2)	120	ISO 7935	On-Line Infra-red analysis for whole of test day.	Yes	Yes
Oxides of nitrogen (NO_x)	121	ISO 10849	On-Line Infra-red analysis for whole of test day.	Yes	Yes
Carbon dioxide (CO_2)	122	ISO 12039	On-Line Infra-red analysis for whole of test day.	Yes	Yes
Total organic carbon (VOCs)	123	EN 12619	On-Line analysis by flame ionisation detection for whole of test day.	Yes	Yes

A full velocity traverse was required to allow the reference velocity data (from a pitot probe at a single point) to be referenced to the average velocity flow through the duct. The full traverse could only be undertaken on the ‘live’ plant as most had no flow outside the combustion periods. However, a significant amount of equipment was placed in and around the stack during the tests; this equipment, together with the high temperature of the stack when incineration was underway, created safety issues when attempting a velocity/temperature traverse of the sampling axes. Consequently, few traverses could be undertaken during the test periods.

The pitot probe placed with the particulate and dioxin sampling train was continually recording the velocity at the sampling point.

A continuous emission monitoring system (CEMS) was used to determine concentrations of NO_x, SO_2, CO, CO_2 and O_2. The CEMS was operated from the start up of each incinerator where practical and tests continued for such time as to be concurrent with the extractive sampling. When time allowed, the CEMS was operated for the whole combustion period in order to gather data for start up, normal combustion conditions and the final phase when burners were turned off.

The HCl gaseous component was determined using an integrated wet chemical method which collected sample over a period of 1 to 3 hours. Integrated samples for SO_2 were also collected as it was considered likely that SO_2 concentrations would be close to the limit of detection of the SO_2 CEMS.

After the furnace had cooled, representative samples of the residual ash were taken for analysis for carbon, loss on ignition and nitrogen.

Measurement Uncertainty - The estimation of the measurement uncertainty is tabulated as a budget from the percentage uncertainties for each component that contributes toward the results. Hence, for the measurement of a parameter such as sulfur dioxide the following percentage errors were taken into consideration:

- Metered gas volume, 2%
- Sample volume measurement, 1%
- Sample analysis, 10%
- Blank analysis, 20%

Together with the uncertainties of temperature, pressure and oxygen readings taken the overall measurement of uncertainty is calculated using a coverage factor of 2 which provides a level of confidence of approximately 95%. In principle, the uncertainty is calculated and given in the same unit as the actual result.

2.3 ASSESSMENT OF AIR POLLUTION RISKS AND THE NEED FOR CONTROLS

The air pollution burden from small carcass incinerators were quantified in terms of the measurements at the sample sites to provide the following estimates:

a) Average, maximum and minimum emission from individual incinerators, accounting (to the extent possible) for variation in figures relative to material throughput. Residual variation in the data is likely to reflect differences in the quality of incinerator, deviation from best practice, etc. ; and

b) Total emissions of each pollutant.

The assessment of air pollution risk was quantified in the following ways:

1) In terms of emissions. Estimation of total environmental burdens was carried out through extrapolation using the upper estimate (2600) of the number of incinerators provided by ADAS and the mean emission of each pollutant from the incinerators monitored. Extrapolated emissions of monitored pollutants were then compared for significance with total UK emissions of each pollutant, and national sectoral emissions for example incineration, transport, agriculture etc;

2) In terms of potential exceedance of air quality limits under the National Air Quality Strategy, and the Daughter Directives to the EU Framework Directive on Ambient Air Quality. This, and point 4 in this list, are measures of risk against regulatory compliance;

3) In comparative terms, against standards for other incineration technologies; in particular to compare emissions with a large centrally located animal remains incinerator operated to meet Waste Incineration Directive emission standards.

4) In comparative terms, against national emission ceiling targets to assess the significance of the impact of emissions from the small-scale incinerators to national targets.

2.4 IDENTIFICATION OF BEST AVAILABLE TECHNIQUES

Previous tasks identify the emissions and the achievable performance benchmarks for these incinerators and their associated pollution risks. In this task these data were used to identify and evaluate best available techniques (BAT) for the incineration of these wastes. The evaluation of BAT included the consideration of:

- diverting waste to a central incineration facility; and
- replacing the current UK small incinerator mix with the least polluting model.

Accordingly, the first step in the task was to provide a qualitative analysis of the issues associated with each key pollutant. Comments are provided on each pollutant’s impact on each of the following issues:

- **Public health** (for example respiratory effects caused by exposure to sulfur dioxide)
- **Nuisance effects** (likely to be principally odour and dust but potentially noise also).
- **Public perception of the relative importance** of each issue/ pollutant
- **Animal health implications** (for example effects of livestock exposure to pollutant releases).

Following this qualitative analysis, the assessment proceeded to a quantitative analysis of best available techniques. These techniques included both management controls (for example good housekeeping) and technical controls (for example the fitting of end-of-pipe abatement). Task 3 provides much of the background analysis required for this part of the work.

The assessment provides a measure of the emission savings from two scenarios:

- Scenario 1: Diversion of animal carcasses to a central incinerator; and
- Scenario 2: Replacement of current mix of on farm incinerators with the best available small carcass incinerator model.

Scenario 1 required the assessment of four key issues:

a) Emissions from small carcass incinerators.
b) Emission limits for large central incinerators, based on the waste incineration directive.
c) Emissions and other burdens from the transport of material to large central incinerators (transport distances, required for assessment of these emissions, can be based on knowledge of the location of the small and large incinerators).
d) Potential for contamination of vehicles, etc., with animal wastes.

Accordingly, the analyses present both the emission savings of each scenario and an appraisal of their practical implementation.

The analysis of Scenario 2 required assessment of:

a) Emissions from small carcass incinerators.
b) Emissions from the best performing small-scale incinerator monitored.
c) Localised health and pollution risks.

3 Literature Survey

There is little information available in the literature on small-scale incineration plant. Much of the data that are available concern best practice with respect to operation of these facilities. In Europe, it appears that regulators largely ignore these incinerators. In the United States it appears that similarly sized incinerators situated in rural areas are exempted from emission controls on the basis of hygiene being more important than air-borne emissions. In the absence of controls, many US states provide guidance on the siting and operation of these plant for example specifying that incinerators should be sited on a concrete apron, and a minimum distance from water courses, housing and other receptors.

In Denmark, small-scale incinerators are not known to be used on farms. Instead farmers pay renderers to pick up their animal carcasses for example fallen livestock.

In France, domestic pets are incinerated at small private pet crematoria; these are private sites and incinerate animals from several sources. However, there are no data collected for these pet crematoria. Cattle are incinerated in large specialised incinerators known as ‘Equarrassage’. Small animals such as chickens are collected from farms in a public service and burnt in a centralised and controlled incinerator. The farm livestock incinerators come under specific environmental regulations. The districts are responsible for their regulation.

In Austria, Belgium and Germany, it appears that the use of these incinerators is prohibited and instead animal remains are sent to larger centrally located incineration facilities.

In Finland, there are less than 30 low capacity on-farm incinerators for the disposal of poultry carcasses on poultry farms and each of these are regulated by local veterinary and environmental authorities.

In Norway, according to the Ministry of Agriculture, on-farm incinerators do not exist.

In Sweden, there are 28 on-farm small incinerators approved by the Swedish Board of Agriculture. The main purpose of these is burning straw or wood in order to provide heating for farm buildings. However, carcass incineration is permitted provided no more than 60 kg are placed in the incinerator during any time and only animals from the farm where the incinerator is located may be burned. In addition, the incinerator must:

- be located outside “city planned” area (otherwise special rules apply)
- be constructed for solid fuel (straw, wood) only
- be constructed for a capacity not more than 500 kW (again, otherwise special rules apply)
- be equipped with O_2 control for the control of residues in outlet gas
- incineration at a temperature not less than 850ºC.

Swedish regulations require animal remains only be incinerated within a hot incinerator and the carcasses must be applied on top of straw/wood. The Ministry of Agriculture also requires control of complete incineration after each incineration and a specific hygiene programme must be drawn up and followed by the operator. In addition to these requirements, the operator must keep and maintain records of incinerator operations, to be kept for two years, including details of the type of material incinerated, quantity and date of incineration.

The literature survey suggests that although small animal carcass incinerators are used in other countries in Europe and in the USA. The UK usage appears to be far more intensive and subject to less regulation than elsewhere in Europe. New EU Animal By-Product Regulations are due to come into force in late 2002 and these are intended to harmonise regulatory controls on small carcass incinerators across Europe.

The lack of emission data from the literature survey illustrates that the environmental performance of these machines is not well known. Furthermore, the scale of use of small carcass incinerators in the UK clearly illustrates the need for emission data to enable informed policy formulation.

4 Site Assessments

4.1 SITE RECONNAISSANCE VISITS

A total of 14 sites were visited in order to assess them for possible inclusion in the site testing phase of the project. At each initial assessment visit the viability of the site for test work was assessed together with the general operation of the animal carcass incinerator.

The standard of housekeeping on site was also assessed including the provision and storage of fuels used and the manner in which the animal carcasses were stored prior to incineration. From the sites visited it can be fair to say that, in principle, carcasses are not left long before being incinerated and as such it was uncommon to see carcass refrigeration.

The main exception to this was the pet crematoria where fallen animals would be incinerated within a day of arrival but the other animals and material would be put into cold storage to await cremation.

The sites had various standards of cleanliness. In particular, at the hunts and abattoirs (where carcasses were being butchered to provide meat for animal or human consumption), the work areas were often washed down and the waste loaded into the sites' incinerator immediately or stored in vats until space in the incinerator was available. Hence, a common scheme of clean modes of work, tidiness and an organised approach was found. At these sites, use of an on-site incinerator to burn the waste can be considered as a natural extension to the operator's activities.

At other sites, the standard of housekeeping varied a great deal and operation and supervision of the incinerator was similarly variable. Where operators placed the carcasses into the incinerator in good time there was little noticable odour. Even in instances where odour was noticed, the effect diminished rapidly with distance.

The operators were aware of the alternatives to incineration. At most sites, the operators had experience of alternative disposal routes prior to introduction of the incinerator. The site operators disposed of the carcasses commonly by ploughing into fields as in the poultry industry or, the use of middens or, by collection by waste contractor. These local alternative methods had had their own problems for the operators, not least the management of remains for several days. Under the Animal By-Products Order 1999 (ABPO) animal carcasses must be disposed of by rendering, incineration or via an approved outlet (for example a knacker's yard). Ploughing carcasses into land is not a permitted disposal route.

4.2 ISSUES IN COMPLETING EMISSION SAMPLING SITE VISITS

4.2.1 Protocol development visit

It was originally planned that the protocol development visit would also be used in the results set. Unfortunately due to difficulties encountered at the site during the initial visit, it was not possible to use these results. The particulate emission at this site was very high and measurements had to be aborted due to filter blockages and other particulate-related issues. However, lessons were learnt at this site and various different techniques were tested to make the subsequent visits to the other sites more successful.

The protocol development site was visited again at a later date to complete the emission measurements.

Test work at all the other sites was conducted with no significant problems apart from an aborted visit to one site due to severe weather conditions. The team aborted the visit and returned to site a few weeks later to complete the test work. These sites are comparatively exposed and it was found to be impractical to erect substantial weather shelters on the temporary sampling platforms. This was due to the emissions from the stack and the high stack temperature, which ranged up to several hundred degrees Celsius.

4.2.2 Foot and mouth disease outbreak

When the initial protocol development sampling visit was underway in February 2001 the news broke of the first case of the foot and mouth disease (FMD) outbreak. The outbreak interrupted the programme of work since many sites were not allowing any non-essential visits.

Further, many of the AEA Technology staff needed for site work were also involved with the FMD pyre and associated air quality monitoring on behalf of the Environment Agency and DEFRA. Hence, to reduce the risk of spread of the disease, site visits were avoided during this time.

After the risks of the spread of FMD had reduced, the visit schedule was restarted where possible. However, some sites only became available quite late in the project. Further ‘knock-on’ effects were felt with some important sites being unable to burn as frequently. This resulted in having to seek a further site to reasonably complete the site test work with as wide a range of incinerators as possible.

5 Assessment of Air Pollution Risks and the Need for Controls

5.1 EMISSIONS TEST DATA FOR SMALL-SCALE ANIMAL REMAINS INCINERATORS

Experimental results and calculations for each site are detailed in Appendices C to M. Results for individual incinerators are also summarised in Table 2. It was observed that the presence of afterburners made a major difference to emission of some pollutants, so results are grouped according to presence or absence of this technology. The ages of the plant ranged from five months to six years, with a median age of twelve months.

Table 2 Summary of incinerator emissions

Site	Location	Fuel	TPM	SO_2	HCl	CO	NO_x	VOCs	Dioxins & furans	CO_2
			$mg.m^{-3}$	$mg.m^{-3}$	$mg.m^{-3}$	$mg.m^{-3}$	$mg.m^{-3}$ (as NO_2)	$mg.m^{-3}$ (as C)	$ngITEQ.m^{-3}$	%
Incinerators with afterburners										
1	Abattoir	Propane	27	77	39	4.2	614	1	0.06	7.3
3	Pet crematorium	Heating oil	106	190	23	150	234	23	0.40	8.1
4	Poultry farm	Propane	58	179	58	1030	381	61	0.19	7.2
7	Poultry farm	Propane	68	169	24	3990	236	322	0.07	7.0
8	Farm	Red diesel	749	265	9	6310	247	10000	0.14	6.8
9	Pig farm	Diesel	36	376	24	1650	376	117	0.10	7.6
10	Poultry farm	Propane	90	34	8	1620	303	484	0.10	6.9
11	Hunt kennels	Propane	373	164	60	1760	230	1170	0.23	6.9
	Minimum		*27*	*34*	*8*	*4*	*234*	*1*	*0.06*	*6.8*
	Maximum		*749*	*376*	*58*	*6310*	*614*	*10000*	*0.40*	*8.1*
	Average		*188*	*181*	*30*	*2063*	*327*	*1523*	*0.16*	*7.2*
Incinerators without afterburners										
2	Poultry farm	Kerosene	107	456	112	348	225	869	0.08	7.7
5	Pig farm	Gas oil	173	127	26	1180	129	78	0.21	7.5
6	Pig farm	Oil	277	313	56	5840	352	3490	0.05	9.0
	Minimum		*107*	*127*	*26*	*348*	*129*	*78*	*0.05*	*7.5*
	Maximum		*277*	*456*	*112*	*5840*	*352*	*3490*	*0.21*	*9.0*
	Average		*186*	*284*	*65*	*2453*	*235*	*1480*	*0.11*	*8.1*
All sites										
	Minimum		27	34	8	4	129	1	0.05	6.8
	Maximum		749	456	112	6310	614	10000	0.40	9.0
	Average		187	213	40	2170	302	1510	0.15	7.7

Concentrations are standardised to mass concentrations at 11% O_2 , dry and STP (0°C, 101.3 kPa) which is the normal standardisation condition for waste combustion processes.

Table 2 demonstrates a large variation in emissions of most pollutants between the incinerators tested. Plant fitted with afterburners generally give rise to significantly less environmental emissions for nearly all the pollutants measured, with the exception of emissions of oxides of nitrogen. Increased emission of oxides of nitrogen is consistent with the higher heat input into the incinerator from the afterburner.

Emission rates for each site are summarised in Table 3, these have been used with the typical burn periods to determine the emission of each pollutant per operating cycle (Table 4).

Table 3 Incinerator emission rates

Site	**Location**	**Fuel**	**TPM**	**SO_2**	**HCl**	**CO**	**NOx**	**VOCs**	**Dioxins**	**CO_2**
			$kg.h^{-1}$	$kg.h^{-1}$	$kg.h^{-1}$	$kg.h^{-1}$	$kg.h^{-1}$ (as NO_2)	$kg.h^{-1}$ (as C)	$ng.h^{-1}$ (ITEQ)	$kg.h^{-1}$
Incinerators with afterburners										
1	Abattoir	Propane	0.013	0.037	0.019	0.002	0.298	0.001	28	43
3	Pet crematorium	Heating oil	0.040	0.068	0.009	0.054	0.082	0.008	121	114
4	Poultry farm	Propane	0.016	0.048	0.016	0.276	0.103	0.017	49	26
7	Poultry farm	Propane	0.035	0.090	0.013	2.11	0.123	0.170	40	41
8	Farm	Red diesel	0.21	0.080	0.002	1.68	0.081	2.60	49	40
9	Pig farm	Diesel	0.008	0.088	0.006	0.389	0.088	0.027	22	37
10	Poultry farm	Propane	0.013	0.005	0.001	0.238	0.045	0.072	15	41
11	Hunt kennels	Propane	0.21	0.090	0.034	0.986	0.127	0.656	124	75
	Average		*0.067*	*0.063*	*0.012*	*0.716*	*0.118*	*0.443*	*56*	*52*
Incinerators without afterburners										
2	Poultry farm	Kerosene	0.031	0.133	0.033	0.105	0.064	0.220	27	25
5	Pig farm	Gas oil	0.079	0.056	0.012	0.533	0.058	0.753	91	50
6	Pig farm	Oil	0.060	0.068	0.012	1.25	0.076	0.170	9	60
	Average		*0.057*	*0.086*	*0.019*	*0.630*	*0.066*	*0.336*	*42*	*45*
Results for all sites combined										
	Average		*0.065*	*0.070*	*0.014*	*0.693*	*0.104*	*0.414*	*52*	*50*

The emissions of nitrogen oxides from liquid fuels would be expected to be higher than those from gaseous fuels and concentration data from several of the sites appear to contradict this. This is likely to be due to differing burner sizes (thermal input) and combustion chamber temperatures.

The determined dioxin concentrations are generally low with about half the incinerators indicating compliance with WID limits. The data for both groups of incinerator can be considered to show close agreement when the expected uncertainty of ± 50% in the reported data is considered.

Table 4 Summary of average emissions per operating cycle

Site	Location	Fuel	TPM	SO_2	HCl	CO	NO_x	VOCs	Dioxins & furans	CO_2
			kg	kg	kg	kg	kg (as NO_2)	kg (as C)	ng (ITEQ)	kg
Incinerators with afterburners										
1	Abattoir	Propane	0.09	0.26	0.13	0.01	2.09	<0.01	190	302
3	Pet crematorium	Heating oil	0.16	0.27	0.03	0.22	0.33	0.03	480	458
4	Poultry farm	Propane	0.06	0.19	0.06	1.10	0.41	0.07	190	106
7	Poultry farm	Propane	0.21	0.54	0.08	12.6	0.74	1.0	240	246
8	Farm	Red diesel	1.2	0.48	0.01	10.1	0.49	16	290	241
9	Pig farm	Diesel	0.08	0.88	0.06	3.9	0.88	0.27	220	367
10	Poultry farm	Propane	0.08	0.03	0.01	1.4	0.27	0.43	90	246
11	Hunt kennels	Propane	1.2	0.54	0.20	5.9	0.76	3.9	750	451
Incinerators without afterburners										
2	Poultry farm	Kerosene	0.25	1.1	0.26	0.84	0.51	1.8	210	200
5	Pig farm	Gas oil	0.79	0.64	0.12	5.3	0.58	0.35	910	505
6	Pig farm	Oil	0.30	0.31	0.06	6.3	0.38	3.8	50	302

The emissions in Table 4 provide an indication of the range of releases over a typical operating cycle for each incinerator.

It should be noted that even small-scale incinerators equipped with an afterburner but poorly operated and/or maintained (for example overloaded) can give rise to much greater emissions of most pollutants than a simpler design, not equipped with an afterburner, but carefully operated. For example, emission concentrations of particles, CO and VOCs at site 8 are significantly higher than for most of the other incinerators monitored, although this incinerator is equipped with an afterburner. This demonstrates the need for plant operators to be properly trained in the use of the equipment, and to understand the consequences of poor maintenance and operating procedures.

Carbon dioxide emissions are primarily governed by the carbon content of fuel burned and the wastes incinerated, with combustion efficiency an additional factor. Similarly sulfur dioxide emissions are directly proportional to the sulfur content of the fuel used and waste incinerated. Although no analysis of the fuels was undertaken, refined gaseous fuels have negligible quantities of sulfur compounds and consequently the sulfur emissions determined at these plant are due to sulfur in the animal remains. The sulfur content of gas oil or diesel is regulated but with no information on the composition of the fuels, it is difficult to provide informed comment on the contribution from the animal remains.

Units firing on near sulfur free oil or gas will certainly produce lower sulfur dioxide emissions than those firing on conventional heating oils, when burning comparable wastes. Legislation still to be fully implemented on the sulfur content of fuels will have a significant impact on emissions of this pollutant from fuel inputs over the next few years. It will not, however, affect emissions arising from the sulfur contained in animal carcasses.

5.2 CURRENT EMISSION LIMITS AND BENCHMARKS

At present there are no emission limits, in the UK, applicable to small (<50 kg/hr) incinerators. However, there are a number of Process Guidance documents available for similar, albeit larger scale activities under Local Authority Air Pollution Control, providing benchmark release limits. In addition, the European Commission's Waste Incineration Directive [WID (2000)] defines mandatory maximum release limits for all other incineration plant.

These benchmarks and limits are reproduced in Table 5 and provide a comparison with measured releases; of these, those benchmark releases given for animal remains incineration are most appropriate for comparison. Whilst it is highly unlikely that current small-scale incinerators will comply with all the Waste Incineration Directive (WID) limits they are an important benchmark as future revisions of Process Guidance notes will need to reflect the WID limits.

Table 5 Current emission benchmarks and limits

Pollutant	Units	Part B Benchmarks (as given in Process Guidance Notes)				Waste Incineration Directive Limits
		Clinical Waste	Animal Remains	General Waste	Crematoria	
Particulate matter (TPM)	$mg.m^{-3}$	30	100	30	80	10
Sulfur dioxide (SO_2)	$mg.m^{-3}$	300	300	300		50
Hydrogen chloride (HCl)	$mg.m^{-3}$	30	100	30	100	10
Carbon monoxide (CO)	$mg.m^{-3}$	50	100	50	100	
Oxides of nitrogen as NO_2	$mg.m^{-3}$					400
Volatile organic compounds as carbon	$mg.m^{-3}$	20	20	20	20	10
Dioxin/furans	$ngITEQ.m^{-3}$	1		1		0.1

For most incinerators the measured pollutant emission concentrations are higher than several of the emission limit values in Table 5, including many of the less exacting limit values. This is not surprising as there are no emission limit values applied to animal remains incinerators smaller than 50 kg/h. These units are currently unregulated (except for nuisance and smoke issues).

Site 1 was unusual in meeting emission standards for larger animal remains incinerators and crematoria. However the site has the highest NO_x emission concentration. This suggests high fuel use to achieve the high degree of emission control. Emission of HCl is higher than some of the other units tested but, like SO_2 and CO_2 the emissions from unabated plant are dependent on the composition of the waste materials and fuel.

Dioxin emissions are generally very low for all the incinerators monitored and several of the units tested demonstrated compliance with the WID limit of $0.1ngTEQ.m^{-3}$. However, the emission limits set within the WID are significantly exceeded for all the other pollutants measured.

5.3 INCINERATOR ASH RESIDUES

A summary of the analysis of ashes collected during the test programme are provided in Table 6. Ash was not collected at several of the plant due to the presence of large quantities of uncombusted animal remains including blood.

Table 6 Ash analysis

Site	Analysis (%)			Comments
	Loss on ignition	Total Organic Carbon	Nitrogen	
Incinerators with afterburners				
1	7.6	11.2	0.91	
3	16.3	3.7	0.76	
4	13.3	7.2	0.99	
7	11.9	4.4	0.69	
8	8.0	5.3	0.54	
9	-	-	-	Samples collected but not analysed as significant residual organic matter
10	-	-	-	Samples collected but not analysed as significant residual organic matter
11	2.3	1.0	0.10	
Incinerators without afterburners				
2	2.4	2.8	0.32	
5	8.0	5.3	0.54	
6	-	-	-	Samples not collected due to blood and large parts of carcass remaining.

Site 11 has the lowest residual carbon and nitrogen content indicating higher degrees of burn out than the other units. In common with some of the small poultry units, this incinerator had underfire burners and fire bars to support the animal remains above the main burners. However, although the ash is comparatively clean, and afterburners were fitted, this incinerator had amongst the highest emission concentrations found in the survey.

5.4 CONTRIBUTION OF SMALL-SCALE CARCASS INCINERATION EMISSIONS TO TOTAL UK EMISSIONS

Table 7 presents the estimated emissions of each key pollutant from small-scale animal carcass incinerator emissions together with the contribution from other sources and the latest published national totals, as reported in the UK National Atmospheric Emissions Inventory [NAEI (1999)].

The total emissions from the small incinerators were extrapolated from the results of the monitoring from the incinerators monitored. It has been assumed that a total of 2600 units were in use and that each unit operates for an average of 35 hours per week for 52 weeks per year (i.e. 1820 operational hours per annum).

PM_{10} emissions from the incinerators were not measured, only total particulate matter (TPM) was measured. Therefore the PM_{10} figures are based on a worst case assumption that all the particulate matter is comprised of PM_{10}. Accordingly, the PM_{10} figures provided for these small incinerators may be overestimated.

The emissions from small carcass incinerators are not currently accounted for directly within the NAEI due to the absence of information on these sources. However, it is likely that some of the emission (the part due to combustion of fuel) is included in the NAEI.

The results from this study demonstrate that the contribution of emissions from small carcass incinerators to the national total is very low at or less than 0.2% for all the measured pollutants.

Table 7 Contribution of incineration to total United Kingdom emissions of key pollutants in 1999

Source (SNAP sector)	PM_{10} (kt)	SO_2 (kt)	HCl (kt)	CO (kt)	NOx (kt)	VOC (kt)	Dioxin gITEQ	CO_2 (kt)
					(as NO_2)	(as C)		(as C)
Combustion in energy production (01)	26.1	883.6	82.2	94.4	422.5	10.3	31.1	49415.8
Combustion in domestic and commercial (02)	42.6	74.5	7.1	269.4	103.4	46.0	89.7	31469.0
Combustion in industry (03)	19.0	155.6	8.5	172.7	169.4	6.6	125.1	23022.9
Production processes (04)	35.8	17.4	0.1	475.9	6.1	212.2	25.1	3721.7
Extraction/distbn of fossil fuel (05)		1.2		1.0	1.2	258.5		241.0
Solvent use (06)		3.6				471.6	0.4	
Road transport (07)	36.3	12.2	0.0	3292.6	713.6	472.6	12.5	31243.7
Other transport (08)	10.7	34.7	0.0	437.3	185.0	63.5	0.5	4415.1
Waste treatment (09)	1.4	4.3	0.1	16.6	3.5	24.5	55.6	1365.6
Agriculture & forestry, land use (10)	14.0							234.4
Nature (11)						178.0	5.8	
Total UK emissions (1999)	***186***	***1187***	***98***	***4760***	***1605***	***1744***	***346***	***145130***
Total UK emissions from agriculture activities in all sectors note 1								
Total agriculture related emissions	19	4.4	0.02	23	27	5.6	7.8	914
Estimated total UK emissions from Small-scale carcass incinerators								
Small carcass incinerators	0.31 note 2	0.33	0.07	3.3	0.49	2.0	0.25	65
Small-scale carcass incinerators contribution to agriculture total (%)								
	1.6 note 2	7.5	>100	14	1.8	35	3.2	7.1
Small-scale carcass incinerators contribution total national emissions (%)								
	0.17 note 2	*0.03*	*0.07*	*0.07*	*0.03*	*0.11*	*0.07*	*0.04*

Note 1 The NAEI Agriculture, forestry and land use source sector does not include emissions from process plant and off road vehicles (for example). The total figures for agriculture include emission contributions from the Agriculture, Other transport and Combustion sectors.

Note 2 Figures provided are for total particulate matter and therefore may overestimate of PM_{10} emissions and contribution.

However, emissions of several pollutants from the incinerators are significant when compared with the totals provided for agriculture, in particular the emission of HCl which appears to exceed the UK total for the agriculture components of the inventory.

Revision of NAEI estimates to include emissions of SO_2, CO, VOC and CO_2 from these plant would significantly increase the budget of agriculture-related activities in the NAEI. However, the impact on UK total emissions from revisions to include small carcass incinerators would be small.

5.5 CONTRIBUTION TO NATIONAL EMISSION CEILINGS

The National Emission Ceiling Directive [NECD (2001)] defines limits for the release of certain pollutants from 2010. The impact that emissions from small carcass incinerators may have in 2010 on UK emission ceilings are summarised in Table 8. The UK emissions are extrapolated for all the expected 2600 small-scale carcass incinerators assuming, as before, an average of 1820 operational hours each per annum and assuming that current emission levels will remain constant to 2010.

Based on these assumptions, Table 8 demonstrates that the contribution of small carcass incinerators to the National Emission ceilings in 2010 is negligible at or below 0.1% for sulfur dioxide and nitrogen oxides and, less than 0.2% for volatile organic compounds.

Table 8 Contribution of small carcass incinerator emissions to the national emission ceilings in 2010

Pollutant	Sulfur dioxide (kt)	Nitrogen oxides (kt)	VOCs (kt)
UK National Emissions Ceiling to be attained by 2010	585	1167	1200
Total emission from small carcass incinerators	0.31	0.49	2.0
% contribution to target	0.05%	0.04%	0.17%

6 Identification of Best Available Techniques

6.1 OVERVIEW

The emissions, pollution risks and the achievable performance benchmarks for small carcass incinerators have been established in the previous section. Based on the results already discussed, and the analysis of a number of proposed scenarios, the best available techniques (BAT) are identified. The first step to establish BAT for small carcass incinerators is a qualitative analysis of the issues associated with each pollutant. An impact assessment of each pollutant has been carried out. The next stage in assessing BAT is qualitative; several alternative scenarios to the current situation were assessed for their effectiveness. Finally, conclusions are drawn on the BAT for small carcass incinerators.

6.2 POLLUTANT IMPACT ASSESSMENT

6.2.1 Main pollutants and Impacts

The most important pollutants are shown in Table 9. In some cases the effects listed are not directly caused by pollutants as emitted, but are caused by secondary pollutants formed through chemical reaction in the atmosphere. An overview of the impacts associated with the pollutants measured during this study is provided in Table 10. The Table is intended as a general guide.

Table 9 Main pollutants

Primary pollutant	Secondary pollutants
Nitrogen monoxide	Nitrogen dioxide, nitrate particles, ozone
Volatile organic compounds	Ozone and other photo-oxidants
Sulfur dioxide	Sulphate particles
Carbon monoxide	Ozone and other photo-oxidants

Table 10 Health and environmental impacts of eight major pollutants

Pollutant	Global warming	Ozone depletion	Acidification	Ground ozone	Eutrophication	Odour	Amenity effects	Materials damage	Crop damage	Human risk	Persistence	Bioaccumulation
Particulate	x						x	x		x		
Sulfur dioxide			x					x	x	x		
Hydrogen chloride			x					x		x		
Carbon monoxide				x						x		
Oxides of nitrogen			x	x	x			x	x	x		
Volatile organic compounds	x			x		x		x	x	x		x
Dioxins and furans										x	x	x
Carbon dioxide	x											

6.2.2 Health impacts

Epidemiological and other data indicate that several of the pollutants of interest here are harmful to health at ambient concentrations [COMEAP (1999)]. Increases in mortality rates, hospital admissions and various lesser effects have been identified. The strongest evidence points to PM_{10}, followed by ozone and SO_2.

Evidence on NO_2 and CO is weaker, though the mechanism of CO reaction with oxyhaemoglobin is of course well known. CO at ambient concentrations is not responsible for the deaths reported regularly as a consequence of the use of faulty water heaters or inhalation of car exhaust fumes.

Over 95% of human exposure to dioxins is through the food chain, mostly through the consumption of meat, fish and dairy products. Direct exposure through air pollution is therefore relatively minor.

Although the Food Standards Agency's Committee on Toxicity [COT (2000)] concluded that current concentrations of dioxins and dioxin-like PCBs in food are unlikely to pose a risk to health. Effects on neurodevelopment and neurobehaviour (object learning) and effects on thyroid hormone status have been observed in children exposed to dioxins and / or PCBs in the womb, at exposures at or near background environmental levels. However, it is not clear to what extent dioxins are responsible for these effects, especially considering the chemical mixtures to which human individuals are exposed. However, it has been recognised that effects might already be occurring in the general population at current background levels of exposure.

6.2.3 Damage to materials
Acidifying pollutants, particularly SO_2 cause deterioration of stone, metal and other building materials. This problem led to severe damage to historic buildings in many European cities in the 19th and 20th centuries. However, action to limit sulfur emissions in urban areas has reduced such impacts considerably. Ozone is known to damage rubber and some paints, though effects on the latter seem relatively insignificant in the UK [Holland *et al*, (1998)].

6.2.4 Ecological damage
Ozone is known to reduce crop yield. SO_2 also affects yield, though the current concentrations in rural areas, combined with the effects of modern intensive agriculture on soil nutrient content mean that deposited SO_2 can act as a source of fertiliser. This effect, however, seems to be insignificant.

More serious effects arise through the deposition of acidifying pollutants to ecosystems in areas, such as many parts of northern Europe, where soils are acid-sensitive through limited availability of base cations (calcium etc.).

6.2.5 Climate change impacts
The emission of most significance here, so far as small incinerators are concerned, is CO_2. However, other pollutants such as ozone and sulphate and nitrate aerosols are also involved to some degree. The aerosols tend to have a short-term cooling effect. Various reports of the Intergovernmental Panel on Climate Change (IPCC) provide insight on the wide diversity of impacts linked to climate change on health, buildings, agriculture, energy demand, water resources and so on [IPCC (2001a-c)].

6.3 PUBLIC PERCEPTION

A public opinion survey was conducted, on behalf of the former DETR, in 1997 on the public perception of environmental issues. On-farm incineration is related to several of the issues in the survey and these are summarised in Table 11. 41% of people were ‘very worried’ about fumes and smoke from factories, which might reasonably be taken to reflect aversion to small incinerators also. Concerns over acid rain and global warming are also prominent. However, more people were worried about drinking water quality (39%) than global warming (35%), thus burying the animal carcasses as opposed to burning them may be perceived as less acceptable due to the risk water supply contamination. Burial of animal carcasses under ordinary circumstances is also illegal under the 1999 ABPO.

Table 11 Public perception of environmental issues.

Unshaded cells identify the issues most closely related to small incinerators; mid-grey shading identifies those issus with limited relation to small incinerators; dark grey shading identifies unrelated issues.

Issue	% of the population of England and Wales 'very worried' by each issue
Radioactive waste	60
Toxic waste: disposal & import	60
Traffic exhaust fumes & urban smog	48
Ozone layer depletion	46
Use of insecticides and fertilizers	46
Loss of plants and animals in the UK	45
Loss of plants and animals abroad	44
Tropical forest destruction	44
Traffic congestion	42
Fumes & smoke from factories	41
Drinking water quality	39
Global warming	35
Effects of livestock methods	33
Acid rain	31
Smoking in public places	28
Difficulty in traveling by means other than car	26
Decay of inner cities	23
Using up UK's natural resources	23
Need for greater energy conservation	22
Household waste disposal	22
Not enough recycling	18
Noise	15

6.4 NUISANCE

Nuisance includes emissions of smoke and odours. For many on-farm incinerators any such problem will generally be contained within the boundaries of the farm. However, for incinerators sited closer to residential areas (for example at abattoirs, meat processors and hunt kennels), emissions are more likely to cause nuisance.

Smoke from incinerators is associated with poor combustion as a result of furnace design, operation or maintenance. Odours may also be associated with these factors but also with animal remains storage and handling practices.

On one of the sites visited, animal remains were kept within a refrigerated enclosure. On some other sites, remains were deposited within bins equipped with lids and were incinerated within 24 hours; thus odours from feedstock storage and handling were prevented or minimised.

However, on other sites animal remains were left in the open and for several days before incineration. This practise can present a hazard to health and give rise to unpleasantly strong odours. The practise is also in contravention of the 1999 ABPO which requires that disposal is carried out ‘without undue delay’.

6.5 IMPACT OF EMISSIONS ON LOCAL AIR QUALITY

A simple model for short and medium range dispersion of pollutants into the atmosphere was used to calculate annual average concentrations in the surrounding area [NRPB (1979)]. A typical combined plume and stack height was assumed to be 10m and concentrations of pollutants were calculated at distances of 100m, 200m and 1000m from the incinerator using the mean concentrations of pollutants from the eleven incinerators monitored. The model outputs are presented in Table 12.

Table 12 The concentration distribution around a 10m stack (based on mean annual averages)

	Concentration, mg.m^{-3}		
Distance from the stack	**100m**	**200m**	**1000m**
Particulate matter (TPM)	6.3	3.2	0.25
Sulfur dioxide (SO_2)	6.8	3.5	0.27
Hydrogen chloride (HCl)	1.4	0.71	0.06
Carbon monoxide (CO)	67	35	2.7
Nitrogen oxides (as NO_2)	10	5.2	0.40
Volatile organic compounds (as C)	40	21	1.6
		ngITEQ.m^{-3}	
Dioxins/furans	0.000005	0.000003	0.0000002

Table 12 demonstrates that ground level concentrations of all the pollutants examined fall off rapidly with distance from the point of emission. In general, most of these incinerators are located in rural areas, typically at distances greater than 200m from centres of population and with no, or few, additional major emission sources and hence the ground level concentrations will be typically between those provided for 200m and 1000m. Some incinerators may be located much closer to centres of population and thus the concentrations estimated at 100m from the point of emission will be more relevant.

It should be noted that the model does not address potential high ground level concentrations from poor dispersion conditions in which there is potential for grounding of the plume. Such conditions could also arise where siting of the incinerator or stack height is inadequate. In addition, poor location or inadequate stack height may give rise to higher concentrations due to the plume impinging on adjacent buildings (including livestock sheds).

The concentration in the area surrounding the incinerator must be within the National Air Quality Standards (NAQS). These standards are summarised in Table 13 together with the estimated percentage contribution of our modelled emissions to the limits/targets, assuming current levels of emissions do not change significantly over the next 4 years. The results provided in Table 13 demonstrate that for all four pollutants given NAQS targets, a small carcass incinerator would typically contribute less than 0.5% to the each of the total pollutant concentration limits in the area outside a 1km radius of the incinerator. Again the results for particulate matter are an overestimate as, for simplicity, we have used total particulate matter as a proxy for PM_{10} emissions.

Table 13 Concentration contribution from small carcass incinerators to the NAQS at 1000m from the point of emission (based on mean annual averages)

Pollutant	Modelled concentration ($mg.m^{-3}$)	NAQS ($mg.m^{-3}$)	Measured as	To be achieved by	% of NAQS
SO_2	0.27	125	24 hour mean	31/12/04	0.22%
CO	2.7	11600	8 hour mean	31/12/03	0.02%
NOx as NO_2	0.40	200	1 hour mean	31/12/05	0.20%
TPM	0.25	50	24 hour mean	31/12/04	0.50%

It should be noted that most of the standards are expressed as eight or twenty-four hour means and few of the incinerators have a combustion cycle greater than eight hours.

6.6 ANIMAL HEALTH IMPLICATIONS

The animal health implications of exposure to the measured pollutants may be considered as negligible. However, the potential for plume grounding on livestock sheds or pasture needs considered when determining the location of incinerators and stack heights.

Some of the sites surveyed demonstrated poor hygiene and feedstock storage and handling procedures. In particular, practices including leaving fallen stock/carcasses for up to several days in the open and leakage of potentially contaminated materials into soils were observed. The practise is potentially in contravention of the 1999 ABPO which requires that disposal is carried out ‘without undue delay’. These practices may lead to infection by bacteria and/or viruses of groundwater or other animals through vectors including flies and rodents.

In addition some of the sites demonstrated extremely poor combustion resulting in relatively low combustion temperatures and elevated particle emissions. Where diseased animal carcasses are being incinerated, poor combustion may not completely destroy the diseased material and the resulting particle emissions could provide a transport mechanism for disease, and potentially prions, to other animals in the surrounding area via direct inhalation or ingestion of material deposited on to pasture.

Alternatives to on-farm incineration, involving collection of material for disposal at a larger centralised site, may cause problems through the spread of disease from farm to farm. The recent restrictions (official and voluntary) in the UK arising from foot and mouth disease suggests that this could be a significant issue.

7 Evaluation of Best Available Techniques

7.1 BASIS OF EVALUATION

Within this study we have considered three scenarios for analysis of what may be considered as best available techniques (BAT). These are detailed below.

- Diversion of animal waste from farms to a centralised, large animal waste incinerator;
- Replacement of current small carcass incinerators with the lowest emission model found from the measurements taken; and
- Business as usual case (for comparison).

The evaluation is based on potential emission improvements achieved through these scenarios. Several animal health issues (for example the implication of poor combustion and the potential for spreading disease through vehicle movement) have been identified. However, the BAT review in this report does not include a risk assessment of these issues. AEA Technology Environment recommends that a risk assessment is undertaken to ensure that the final choice of disposal methods for animal remains addresses both environmental and animal health issues.

The likely costs of the scenarios have not been considered as this is also outwith the scope of work.

The analysis of the first two scenarios is provided below. The Business as Usual scenario has been described in Sections 5 and 6.

7.2 DIVERSION OF ANIMAL REMAINS TO A CENTRALISED, LARGE ANIMAL WASTE INCINERATOR

In order to simplify this scenario it is necessary to make several assumptions:

- The large animal waste incinerator complies with the concentration limits for new plant in the waste incineration directive.

- The average distance from the central incinerator to a typical farm is 50km (100km round trip)
- Animal carcasses are collected, on average, once a week
- The vehicle used is a diesel fuelled light goods vehicle (LGV).

Table 14 compares the WID limits with the mean concentrations of pollutants measured, together with an evaluation of the degree of abatement that would be required to meet the WID standards, and the estimated emission savings through meeting these standards. An estimate of the emissions associated with transport of the animal carcasses to a central incinerator is provided.

The figures provided in Table 14 identify that in comparison with emissions from incineration, the emissions from transport of remains are negligible. Accordingly transport emissions will be considered no further in this analysis.

Table 14, Annual emissions reductions achieved through Scenario 1 (based on mean emissions)

Pollutant	Small incinerator mean emission ($mg.m^{-3}$)	WID limits ($mg.m^{-3}$)	Abatement required to meet WID (%)	Emission reduction (tonnes)	Transport emission (tonnes)	Net emission reduction (tonnes)
TPM	187	10	95	291	4	287
SO_2	213	50	77	253	0.5	253
HCl	40	10	75	50	-	50
CO	2170	50	98	3204	5	3199
NOx as NO_2	302	400	-32	-160	4	-164
VOCs as C	1510	10	99	1946	1	1945
Dioxins/Furans	0.15×10^{-6}	0.1×10^{-6}	33	8×10^{-8}	-	8×10^{-8}

The largest potential emissions abatement (above 90%) is for VOCs, carbon monoxide and particulate matter, and these emissions are all directly a function of combustion efficiency. A reduction in emissions of acid gases (hydrogen chloride and sulfur dioxide) of about 75% is also predicted though this will be at the expense of consumption of neutralisation reagents and formation of residues which are generally sent to landfill. Interestingly, emissions of nitrogen oxides may increase through the use of a large central facility.

7.3 REPLACEMENT OF CURRENT POPULATION WITH OPTIMISED SMALL SCALE INCINERATOR

In this scenario the impact on emission is assessed by comparing the emissions resulting from replacement of all the small carcass incinerators with the least polluting incinerator assessed. Whilst it is possible that a better overall environmental performance may be achieved by other incinerators not assessed in this study, the use of the "best" performing example in our survey as a benchmark at least identifies achievable standards.

The selected incinerator (site 1) does not indicate the best performance for all the pollutants, indeed the NO_x concentration determined at this incinerator is the highest of all the incinerators tested. Nonetheless, this approach is considered to be better than defining a hybrid incinerator performance drawn from several plant which may not be achievable in practise. The results of the analysis are presented in Table 15.

Table 15 Emission savings through implementation of Scenario 2 (optimised small incinerator)

Pollutant	Small incinerator best results ($mg.m^{-3}$)	Small incinerator mean concentration ($mg.m^{-3}$)	Emissions reduction required to attain best results (%)	Emission reductions (tonnes pa)
Particulate matter	27	187	86	263
Sulfur dioxide	77	213	64	211
Hydrogen chloride	39	40	2.5	1.7
Carbon monoxide	4.2	2170	99.8	3273
Nitrogen oxides	614	302	-103	-508
Volatile organic compounds	1.0	1510	99.9	1958
Dioxins	0.06×10^{-6}	0.15×10^{-6}	60	1.5×10^{-7}

Although HCl emissions would still be a significant contribution in the emissions from agriculture the input to UK national emissions is very low and, the potential increase in UK NO_x emissions would be less than 0.03%. There may be low NO_x burner technology available for the burners used on these incinerators which would help mitigate the NO_x emissions, however, the availability of such technology for such small burners is not known. In addition, improvement to combustion chamber design (for example improved refractory design) may allow a reduction in the fuel requirement and hence a reduction in NO_x emission.

The potential VOC and CO emission reduction is in excess of 99% and the particulate reduction would be about 85% which compares well with Scenario 1.

7.4 RECOMMENDATIONS ON BAT

7.4.1 Centralised incineration facility versus on-site incineration

The ‘Business as Usual’ scenario is not likely to be considered acceptable by the UK or European regulatory authorities.

The centralised facility offers cleaner combustion with better emissions control and supervision is provided within an existing regulatory framework. Indeed, it is the normal disposal route in many developed countries.

Use of a central facility designed to meet WID or equivalent requirements would generally reduce emissions to atmosphere, although perhaps at the expense of NO_x. However, use of pollution control equipment would generate additional waste to land. Potential disease control issues of animal remains storage and of transport need to be assessed. The impact of restrictions on vehicle movements to and from livestock farms also needs to be considered.

The evaluation indicates that significant reductions in emissions to atmosphere are achievable with an optimised small incinerator. Although the improvements in HCl or SO_2 acid gas emissions would not match those achievable with a larger facility and overall NO_x emissions would be higher. Nonetheless, the reductions in other emissions would be similar to those indicated for the large facility. This evaluation indicates that the use of on-site incineration can be considered to represent BAT for animal remains disposal.

Upgrading or renewal of the incinerator population to match the best achievable in this survey is part of the recommendation on of BAT however, BAT should also include other technical and management improvements.

7.4.2 Housekeeping

Good housekeeping practices are essential to ensure hygienic incineration of animal carcasses. The animal remains must be stored in sealed containers and preferably stored in refrigerated units.

The time that the remains are left in storage should be minimised to avoid putrefaction that would cause odour problems, particularly in summer. The waste should also be stored in a designated, enclosed area.

Storage containers should be well sealed to prevent vermin from disturbing the remains and potentially spreading disease. Areas where blood and fat falls should be regularly washed down, with the run off collected and disposed of safely. This is particularly important in potentially diseased animals.

The co-incineration of waste was not observed to an appreciable extent. Use of hygiene bags would aid manual handling and minimise operator contact. However such bags should not be made from halogenated plastics such as PVC.

Protection of the incinerator from weather is important to ensure protection of refractories, seals, the casing and burners. Manufacturers recommend that they are in a weatherproof shelter, though this is often not the case and the incinerator rusts rapidly as it is exposed to wind and rain.

7.4.3 Fuel use and fuel storage

Low sulfur fuels such as gas should be the preferred choice however, the sulfur content of gas oil and other light fuel oils is likely to be progressively reduced and choice of fuel is probably not a significant issue.

Good fuel storage practices are very important, particularly oil fuels. A tank of 1000 litres of gas oil represents a serious hazard to the environment if it fails. The storage tank must be bunded with a secure base.

7.4.4 Operation

Loading - Poor loading of incinerators is considered to be a major problem causing inefficient combustion and increased emissions. The incinerators are legally required to burn at or below 50kg an hour, the manufacturers therefore design them to cope with this load and no higher. Several cases of overloading have been found with up to 400kg of animal carcasses being loaded into the incinerator at once. Overloading the chamber causes several problems:

- Inefficient combustion of the lower carcasses , insulated from the burner by those above it
- Carcasses that are not hot enough are more prone to pyrolize, thus giving off high levels of particles, VOCs and CO
- Carcasses furthest from the burner may not burn at all, on occasions, whole parts of the animals have been left after the full burn cycle. Bones will only burn at very high temperatures

- Forcing the door shut on an overloaded incinerator will create poor door seals, potentially leading to leaks of fat from the combustion chamber, air leaks and thus ineffective combustion
- Overloading the chamber can lead to animals blocking the after-burner and preventing it from firing.

Furnace temperature and burner operation – Correct burner and after-burner operation is important for efficient combustion and for minimising emissions to air. Where possible, furnace should be preheated to at least 850°C before feedstock is loaded to prevent smouldering at lower temperatures. If the carcasses are loaded into a relatively cool furnace i.e. before the burner is switched on, on ignition, there will be a period, of pyrolysis followed by poor combustion. However it is recognised that this would be difficult to achieve, and potentially hazardous to operators, for such small machines

Combustion chamber design – Ideally the incinerators should operate at a temperature of at least 850°C with a residence time of two seconds. However, this may be difficult with such small facilities and, it may be necessary for manufacturers to demonstrate that dioxins emissions are low if these conditions cannot be met.

Refractory linings should be robust and capable of withstanding the rigours of farm use for several years. It should also insulate the chamber well to aid combustion, minimise energy use and prevent major heat loss to the air (high temperatures outside the incinerator are inefficient and could be a hazard to the operator). Door and other seals should be replaceable and part of regular inspection or maintenance regime.

Afterburners – Use of afterburners is essential to minimise emissions of VOC, CO and particulate. The after-burner should be activated well before the main combustion chamber burner is lit so that it is functioning at an optimum temperature. Indeed operation of the main burners should be interlocked with afterburner chamber temperature.

This would help to minimise emissions during the warm-up of the main combustion chamber. The burner and after-burner should both be switched on for the full combustion cycle to ensure minimum pollutant emissions.

Ash handling - Regular de-ashing of the incinerator chamber is important to avoid bridging of material which insulate the wastes being burned from the primary flame. Large bones in the ash are the result of a low combustion chamber temperature. The ash must be disposed of safely. If the carcasses burnt could be diseased, then the ash must be treated as hazardous waste and disposed of accordingly.

7.4.5 Type approval

The environmental impact from the use of small incinerators could minimised by introduction of a type-approval scheme. Although desirable there is little benefit to be gained from a full survey of pollutants. Approval based on design, on operating and maintenance instructions and on particulate, CO and VOC measurement over a number of operating cycles should be adequate. Dioxins measurement may be considered necessary if furnace temperature or residence times do not meet the minimum requirements. However, given the size of the units and the data determined during this investigation this could be considered unnecessary. It may also be helpful to purchasers if energy use were determined.

7.4.6 Operator Training

In order to avoid poor operation, full training on housekeeping, loading, operating and emptying the incinerator should be given. A certificate of use could be given at the successful completion of training and only fully trained individuals should be permitted to operate these incinerators.

8 Conclusions

The following conclusions are based on a literature survey and measurements undertaken on eleven incinerators burning a range of animal remains, with an age range from a few months to five years and considerable variation in the state of maintenance and operational practices.

A BAT evaluation was undertaken based on potential emission improvements achieved through two scenarios:

- Diversion of animal remains to a central, large incinerator
- Replacement of current small carcass incinerators with lowest emission model

The likely costs of the scenarios have not been considered as this was outwith the scope of work.

1. Significant reductions in emissions to atmosphere are achievable with an optimised small incinerator. Although the improvements in HCl or SO_2 emissions would not match those achievable with a larger facility and overall NO_x emissions would increase. Nonetheless, the reductions in other emissions would be similar to those indicated for the large facility. This evaluation indicates that the use of an on-site incinerator with afterburner can be considered to represent BAT for animal remains disposal.

2. The BAT review also includes recommendations on furnace design, operation and management. Improvements are indicated in housekeeping, storage and handling of animal remains, fuels use and storage, residue disposal, operating temperature, loading and, operator training.

3. A type approval system for incinerators is recommended to minimise the opportunity for installation of more polluting designs.

4. Training of operators is recommended and only fully trained individuals should be permitted to operate the incinerators.

5. Although small animal carcass incinerators are used in other countries in Europe and in the USA. The UK usage appears to be far more intensive and subject to less regulation than elsewhere in Europe although new EU Animal By-Products regulations, due to come in force in late 2002 will harmonise regulatory controls on small carcass

incinerators across Europe.

6. The environmental performance of these machines is not well known. Furthermore the scale of use of small carcass incinerators in UK clearly illustrates the need for emission data to enable informed policy formulation.

7. At the hunts and abattoirs (where carcasses were being butchered to provide meat for animal or human consumption), use of an on-site incinerator to burn the waste can be considered as a natural extension to the operator's activities. At other sites, the standard of housekeeping varied a great deal and operation and supervision of the incinerator was similarly variable.

8. Plant fitted with afterburners generally produce less emissions, with the exception of oxides of nitrogen, than incinerators without afterburners.

9. Several of the incinerators perform well against the benchmark releases provided in current guidance for animal remains incinerators prescribed for local authority air pollution control.

10. Dioxin emission concentrations surveyed were less than 1 ng(ITEQ).m^{-3} with several incinerators meeting the Waste Incineration Directive limit of 0.1 ng.ITEQ.m^{-3}.

11. The results from this study demonstrate that the contribution of emissions from small carcass incinerators to the UK national total is very low at (or less than) 0.2% for all the measured pollutants.

12. Emissions of several pollutants from the incinerators are significant when compared with the NAEI totals provided for agriculture, in particular the emission of HCl which appears to exceed the UK total for the agriculture components of the inventory.

13. The contribution of small carcass incinerators to the UK National Emission Ceilings in 2010 is negligible at or below 0.1% for sulfur dioxide and nitrogen oxides and, less than 0.2% for volatile organic compounds.

14. For all pollutants given NAQS targets, a small carcass incinerator would typically contribute less than 0.5% to the each of the total pollutant concentration limits in the area outside a 1km radius of the incinerator.

15. Where diseased animal carcasses are being incinerated, poor combustion may not completely destroy the diseased material and

the resulting particle emissions could provide a transport mechanism for disease, and potentially prions, to other animals in the surrounding area via direct inhalation or ingestion of material deposited on to pasture.

16. Alternatives to on-farm incineration, involving collection of material for disposal at a larger centralised site, may cause problems through the spread of disease from farm to farm.

17. Several animal health issues have been identified. The BAT review in this report does not include a risk assessment of these issues. AEA Technology Environment recommends that a risk assessment is undertaken to ensure that the final choice of disposal methods for animal remains addresses both environmental and animal health issues.

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Appendices

CONTENTS

Appendix A

Organisations and Individuals Contacted

Manufacturers/Suppliers of Incinerators Operating at <50 kg/hour

The list below details the small carcass incinerator manufacturers contacted regarding emissions. The manufacturers were telephoned to request information on their incinerators. Several companies provided brochures and guidance on their equipment. Additional data were obtained through the internet.

A variety of fuels can be used:
- Natural gas
- Propane
- Diesel
- Kerosene
- Oil
- LPG

Many suppliers offered an after burner as an extra addition to the basic incinerator package. Fuel consumption levels were around 5 litres per hour, with higher values quoted for larger incinerators at 12 litres per hour (120kW heat output). The Howden incinerators had a secondary chamber in order to re-circulate gases over the hearth before passing through the afterburner. The incinerators could also be fitted with a thermal oxidiser to reduce emissions for heavy loads (Howden Ltd., 2001).

Manufacturers Contacted

- Addfield - RES Agriparts
- Bodo Fabrications & Equipment
- Ellendale Engineering Ltd
- Refractory Concretes (http://www.refractoryincinerators.co.uk/sites/rcl/index.html)
- Turkington Engineering Ltd
- Wildemere/William Whites Fabrications
- Akramatic Engineering Co Ltd (formerly Sims Engineering) *
- Mr Richard Nugent
- K J Engineering
- Facultatieve Technology (Formerly Evans Universal Ltd) (www.alkhodari.com/companies/kcc/kits/evans/body_evans)
- Howden 3Ts (International) Ltd., (www.3tsinternational.freeserve.co.uk)
- Techtrol Ltd,
- Bevington Engineering, Hampshire - (Previously sold by Harestock & HAAT)
- J. G. Shelton & Co Ltd

- Furnace Construction
- Adament Refractory Settings
- Holliswood Incinerators Ltd,
- Trackman Engineering (sold as Pyropro) *
- http://www.trackman-engineering.co.uk/contact.htm, www.collinsonindustrial.co.uk/html/Framesets/industrial.htm
- Shenandoh Manufacturing Co. Inc. - previously imported from USA by Sowesco *
- Sowesco now part of E. Collinson & Co Ltd
- Ward Enterprises (http://www.wardenterprises.co.uk/frames/frames.html)
- Silentglow, c/o Envirotank (http://web.onyxnet.co.uk/eilenvirotank.onyxnet.co.uk)
- Alphaweld Ltd/Alphaburn Ltd *
- Quality Equipment (Agents for Turkington) (http://www.quality-equipment.co.uk)

* No longer supplying incinerators

National Farmers Union (NFU)

The contact at the NFU was Michael Payne, a technical consultant. He then contacted the Brussels office to request the European farming union contact details. The response from Damian Phillips of the Brussels NGU was to use the 'COPA web-site' agri info section to find the contacts. COPA is the umbrella organisation for farming organisations in the member states. However, after an extensive internet search including the web-sites, the COPA web-site could not be found:

- www.agriinfo.be (no information on entry page - require password to enter)
- http://www.bml.de/home1.htm – German Ministry
- www.maff.gov.uk – MAFF site
- http://www.dainet.de:8080/DAINETENGKATALOG/SAC?F=SUBJ_FD_ENG&C=a* - German agricultural web-site
- extensive searches using search engines

The main contact source for investigating small animal incinerators in the EU was the 'Maison Europeenne de l'Agriculture' Who is Who List. This publication gave several agricultural contacts for each country, the majority of which were farming unions.

EU MEMBER STATES - Summary of Responses

Austria

The contact from the Austrian Ministry of agriculture is based in the Ministry of Veterinary Services. Mr Scherze is an expert on animal waste disposal. The following information was obtained:

- In Austria there are four big rendering plants (known as TBAs in Germany) to which all farm animal waste is sent
- The rendering plant waste in the form of meat and bone meal (MBM) is then incinerated
- The incinerators used are normally large municipal solid waste incinerators, sometimes cement kilns are used as well.

The use of small animal incineration is not approved by legislation in Austria – “there are no small livestock incinerators in Austria”
Pet crematoria are used in Vienna, though the ministry does not know the regulations which apply to them.

Belgium

J Flaba, ingénieur-directeur, Ministère des Classes Moyennes et de l'Agriculture
Service Développement Production Animale, provided the following information:

- ♦ In Belgium, incineration on farms is not permitted.
- ♦ There are no small volume incinerators on farms.

Denmark

H H Pedersen, of Kamba animal disposal company (http://www.kambas.dk), was contacted regarding Danish animal disposal. He raised the following points:

- Small incinerators are not known to be used on farms in Denmark.
- There is some doubt about the legislation in this area.
- Animal by-products are considered waste, and to incinerate waste the EU requirements for incinerators must be followed, which is impossible except for relatively large installations
- It is possible that local authorities will interpret this stance on incineration differently.
- In Denmark all pig carcasses are collected and the disposal bill paid through the slaughterhouse, thus pigs are not incinerated.
- Cows must be disposed of through rendering plants and processed as SRM; ear tagging enables enforcement of this system.
- Some animals are bred by hobby farmers who are not likely to own small incinerators.
- Small farmers call renderers to pick up their animal carcasses, and they pay the costs.
- It is illegal to bury dead animals except pets in Denmark.

France

The French Ministry of Agriculture was contacted. After a telephone discussion with Gregory Matthew, the following conclusions could be drawn:

- Domestic pets are incinerated at pet crematoria that are privately operated. These are centralised facilities, incinerating animals from several sources.
- There are no statistics or data collected for the pet crematoria.
- Cattle are incinerated in large specialised incinerators known as 'Equarrassage'.
- Small animals such as chickens are collected from farms in a public service and burnt in a centralised and controlled incinerator.
- The farm livestock incinerators come under specific environmental regulations. The districts are responsible for their regulation.

Finland

A Finnish veterinary officer (M Suokko of MAF) provided the following information:

- In Finland there are less than 30 low capacity on-farm incinerators for the disposal of poultry carcasses that die on poultry farms.
- Local veterinary and environmental authorities must approve them.

Germany

A report titled 'Technical requirements and general recommendations for the disposal of meat and bone meal tallow' for the German government on meat and bone meal disposal contained a list of contacts. An e-mail was sent to the following organisations enquiring about the number of small animal carcass incinerators in Germany:

- Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Environment Ministry)
- BMU Bundesministerium für Ernährung, Landwirtschaft und Forsten (BML) (Federal Ministry for Agriculture, Forestry and Fisheries)
- Bundesanstalt für Fleischforschung (Federal Office for Meat Affairs)
- AAK Consulting

The response from the BMU was from Adolf Nottdrodt:

- They are not aware of incinerators specifically for large or small animals in Germany
- According to German legislation, both small and large animal carcass incineration could only take place inside a Tierkörperbeseitigungsanstalt (TBA), which is an animal remains disposal facility.

Norway

Contact: The Royal Ministry of Agriculture, Head of Department, G Hagen. To the best of his knowledge on-farm incinerators for the destruction of animal waste are not in use in Norway.'

Contact: The Norwegian Animal Health Authority, Oslo, Superintending veterinary officer, Tor Arne Moen;

- Use of small volume incinerators on farms in Norway is uncommon
- Disposal of animals is usually done in officially approved plants
- There are some plants for the disposal of pets in the regions, regional officers contact details are available at this web-site. (http://www.dyrehelsetilsynet.no/norsk/om/dv_oslo_akershus_ostfold)
- The local veterinary officers contacted confirmed that there are small animal incinerators for euthanized animals (for example pets) in Skien and one in Fredrikstad, Norway.

Sweden

Contact: Susanne Liljenström, Veterinary Inspector, Swedish Board of Agriculture:

- Sweden has 28 small incinerators at farm level approved by the Swedish Board of Agriculture.
- All of them are mainly intended for incinerating straw or wood to produce heat for the buildings on the farm.
- The maximum weight of cadavers that is allowed in the incinerator at a time is 60 kilos.
- Only animals from the farm where the incinerator is located may be incinerated.

Follow up: S. Widell, Swedish Board of Agriculture, Animal Production and Management Division. Requirements for the approval of low capacity on farm incinerators. The incinerator must:

- be located outside "city planned" area (otherwise special rules)
- be constructed for solid fuel (straw, wood) only
- be constructed for a capacity not more than 500 kW (otherwise special rules)
- be equipped with O_2 –steering for the control of residues in outlet gas
- incinerate at a temperature not less than 850 ^oC.

The incineration must be carried out in the following way:

- only fallen stock from that holding may be incinerated
- only to incinerate fallen stock in a hot incinerator
- only 60 kg of carcasses at a time
- the carcasses must be applied on top of straw/wood.

Own checks:

- control of complete incineration after each incineration

- a specific hygiene programme must be drawn up and followed.

Records to be kept for two years and include:
- type of material incinerated
- quantity
- date

Appendix B
Sampling Methods

Sampling Methods

Measurement Protocol

A test protocol was developed based on a protocol developed for the Environment Agency for assessment of a small animal remains incinerator at a pig farm.

The crematoria guidance note PG5/2(95) outlines the main features of a test protocol to take account of several distinct phases of the cremation process. Some of the phases are irrelevant to the animal remains incinerators (for example burning of a coffin) but the rationale of the protocol is essentially the same.

The operating cycle at animal remains incinerators is considerably longer than at a cremator for human bodies (up to 12 hours compared to up to 2 hours). A representative series of tests should as far as possible cover the entire cycle. However, some simplification was undertaken to minimise sampling costs.

The cycle phases identified are:

A. Afterburner temperature raising (where appropriate)
B. Main chamber burner ignition and cremation of remains
C. Calcification
D. De-ashing

The main periods of concern are B and C. Only combustion of support fuel (for example gas oil) at the afterburner is occurring during phase A and little combustion is occurring during phase D.

Particulate and dioxins measurements were undertaken throughout the burn period of two incineration cycles (two tests for particulate and two for dioxins). Close liaison with the incinerator operators was maintained to ensure that the tests were started at the start of the burning phase.

A multipoint sampling strategy is desirable for particulate and dioxins measurements but, for an operating cycle of up to twelve hours, AEA Technology Environment considered that temporal variation would be of greater significance than spatial variation. The crematoria guidance note requires multipoint sampling for particulate at each phase of the cremation process but this is over a far shorter process cycle and several measurements can be undertaken in one day.

ISO 9096 allows single point sampling for small diameter ducts ($<0.9\ m^2$) albeit with a warning that measurement uncertainty will increase.

AEA Technology undertook single point sampling, this approach also had the benefit that particulate and dioxins measurement could be undertaken simultaneously.

Carbon Monoxide, Sulfur Dioxide, Volatile Organic Carbon, Oxides of Nitrogen and Oxygen

An extractive continuous emission monitoring system (CEMS) was deployed to determine carbon monoxide (CO), sulfur dioxide (SO_2), volatile organic carbon (VOC), oxides of nitrogen (NO_x) and oxygen (O_2) concentrations. The measurement of oxygen levels allows the emissions to be standardised to a specific reference condition (in this case 11% O_2).

The combustion gases were monitored continuously using a transportable multi-component stack gas analyser system. Flue gas samples were abstracted from the flue, filtered and passed to the analyser facilities via heated PTFE sampling lines. The VOC monitor (FID) sampled gases directly from the heated lines, whilst the remaining on-line gases were monitored following pre-treatment to dry and condition the flue gases. The on-line monitors employed the following techniques:

- Carbon monoxide levels were monitored using a non-dispersive infra red instrument in accordance with ISO 12039.
- Sulfur dioxide was monitored using an analyser employing non-dispersive infra-red detection in accordance with ISO 7935.
- Volatile organic compounds levels were measured in accordance with EN 12619, using a heated total hydrocarbon monitor employing a flame ionisation detector.
- Oxygen was measured using a paramagnetic analyser in accordance with ISO 12039.
- Oxides of nitrogen were measured using an infra red analyser in accordance with ISO 10849.

The concentration of SO_2 was expected to be low at most sites and consequently an integrated sampling technique was also deployed for determination of SO_2 as the CEMS has a comparatively poor limit of detection.

Hydrogen Chloride, Sulfur Dioxide and Moisture

The concentrations of selected acid gas species were measured using integrated, manual “wet chemical" techniques. Samples of the flue gases were extracted from the duct through a heated glass probe with integral quartz wool filters to remove particulate material. The filtered flue gases were then passed via PTFE lines into chemical absorption trains containing the appropriate absorption solutions. The volume of dry sample was determined using dry gas meters.

The concentration of hydrogen chloride (HCl) was determined by absorption into a cooled impinger train containing demineralised water as required by BS EN 1911. The final solutions were analysed by Harwell Scientifics (UKAS Lab No. 3222) for chloride ions using ion chromatographic techniques.

The concentration of sulfur dioxide was determined by absorption into a cooled impinger train containing 3 % hydrogen peroxide solution as required by ISO 11632. The final solutions were analysed by Harwell Scientifics (UKAS Lab No. 3222) for sulfate ions using ion chromatographic techniques. Samples were collected for SO_2 analysis because of concerns that the likely concentrations of SO_2 would be close to or lower than the limit of detection of the SO_2 CEMS.

Stack gas moisture was determined using a method based on USEPA 4 by passing a sample of flue gas through a cooled, pre-weighed drying train. Each train comprised a condensate catcher and two Drechsel bottles filled with silica gel. A dry gas meter measured the sampled gas volume.

Particulate Monitoring

The particulate sampling was carried out isokinetically in accordance with the requirements of ISO 9096. Sample was extracted from the duct and drawn through a heated ex-stack filter. Before conditioning and transfer to the flow monitoring system.

Isokinetic sampling is where flue gas is drawn through the sample nozzle at a velocity identical to that in the flue duct at the sampling point. Isokinetic sampling ensures that the flow lines of the particles in the flue gas are undisturbed when sampled. The distribution of particle sizes sampled is therefore representative of that in the flue duct.

Particulate material was trapped by a pre-weighed quartz micro-fibre total particulate filter, which removes 0.3-micron particles with an efficiency of greater than 99.9%. After sampling, the filter was re-weighed at AEA Technology’s Culham Laboratory. The mass of particles collected from a measured volume of gas gives the particulate concentration.

Flue gas velocities and temperatures were measured at regular intervals during sampling using a pitot-static probe and thermocouple.

Dioxin and Furan Measurements

Dioxin and dibenzofuran emissions were sampled isokinetically in accordance with BS EN 1948. The entrained sample was extracted from the flue through a heated glass-lined probe, coupled to a heated glass fibre filter assembly, where particulate was removed at or below 130^{o}C. Finally, organic vapours from the whole sample were absorbed onto a cooled XAD-2 resin trap and condensate from a condenser system was collected. Following completion of the sampling, the various fractions were recovered and submitted to Harwell Scientifics (UKAS Lab No. 3222) for analysis. The samples were extracted, cleaned-up and concentrated at the laboratory and then analysed using gas chromatography-mass spectrometer (HRGC-HRMS) techniques for seventeen specific 2,3,7,8 chloro substituted dioxin and dibenzofuran isomers specified by the Environment Agency.

Appendix C
Emission data - Site 1

Appendix D
Emission data - Site 2

Appendix E
Emission data - Site 3

Appendix F
Emission data - Site 4

Appendix G
Emission data - Site 5

Appendix H
Emission data - Site 6

Appendix I
Emission data - Site 7

Appendix J
Emission data - Site 8

Appendix K
Emission data - Site 9

Appendix L
Emission data - Site 10

Appendix M
Emission data - Site 11