1 EXECUTIVE SUMMARY: WR 0608 EMISSIONS FROM WASTE MANAGEMENT PROCESSES

1.1 OVERVIEW

This report reviews a variety of waste management technologies with the view of quantifying emissions of key pollutants and identifying critical gaps in knowledge. This report follows on from the 2005 "Review of Environmental and Health Effects of Waste Management: Municipal Solid Waste and Similar Wastes" produced by Defra. In particular, the report builds knowledge around emerging waste management technologies.

The study, reported here, covered a number of aspects. Central was the collating and provision of data on emissions to air and water from various waste management technologies. However, the study also considered the possible emissions that may arise when facilities are not operating within normal parameters and provided information to place emissions associated with waste management into the wider context.

The authors of the report are grateful for the assistance and time of a number of technical specialists and technology suppliers who provided data to incorporate into the report.

1.2 AIM AND OBJECTIVES

The overall aim of this research was:

To compile the currently available data on emissions from typical and upcoming networks of waste collection, treatment and disposal technologies in a format that could be used later to provide source term data for the assessment of potential impacts; to make assessments about the quality of this data and identify data gaps.

Specific objectives were to:

- *define a structure of the waste collection, treatment and disposal framework to be assessed;*
- *review the availability and quality of emissions data from the defined waste collection, treatment and disposal scenarios;*
- *assess the differences in data for routine and potential non-routine operations;*
- *place the likely emissions from waste processing in the wider context of other routine activities;*
- *arrange a workshop to present key findings to stakeholders;*

- *identify the important data gaps needed to assess the impacts and prioritise the research needs; and*

- *provide a framework under which future assessments of the impact of emissions from waste processing can be commissioned.*

Within the lifetime of the project these aims and objectives were revisited and, where required, the scope was redefined or constrained as needed.

1.3 SUMMARY METHODOLOGY

1.3.1 Overview

In undertaking the study, efforts were made to obtain and present data that were representative of the technology as a whole and allow comparison of different technologies. However, the data also needed to reflect the diversity within each technology and variations in the expected emissions. On this basis, the methodology reflects these needs as well as the need to present robust information upon which decisions can be based.

1.3.2 Data pedigree and benchmarks

There is a very substantial amount of information available from various sources, which is of variable quality and relevance. Within the study design, it was necessary to develop a method of identifying relevant information and identifying how robust the data might be. There was a balance to be struck between the relative weighting given to, for example, a small number of very good quality sources, and a larger number of poorer quality sources. Reflecting the approach used in the 2005 report, a system of assessing 'data pedigree' was developed. This system scored the data based upon four factors to provide an indication of data quality. Consideration was then given to the quantity of data available. The four factors for assessing data pedigree were:

- Country – data from studies originating in the UK were prioritised, followed by Europe and North America and finally the rest of the world.

- Peer Review – data from peer reviewed sources were prioritised, followed by data from process operators and less thoroughly reviewed sources.

- Methodology – data obtained using a recognised international standard method (for example European Standards or ISO Standards) were prioritised, followed by data obtained using other nationally recognised standards, and followed by other data.

- Operational scale – Data from full scale operational plants were prioritised, followed by data from pilot or experimental scale plants and lastly, laboratory scale studies.

As far as practical, a single, common reference method was used to allow emissions from different processes to be compared. In light of the available data and reflecting the approach that was successfully utilised in the 2005 report, emissions to air were presented on a grams emission per tonne of waste processed basis and to water in terms of milligrams per litre.

In order to provide context for the emissions arising from the various waste management technologies considered, the emissions identified were 'benchmarked' against emissions from landfill and Energy from Waste (EfW). For key pollutants, the emissions from landfill and EfW were determined; the emissions arising from each technology of interest were then 'benchmarked' against these. This approach provided a means of readily comparing 'like-for-like' emissions for each technology considered against a standard baseline. The one exception to this approach, was for cement works where such a comparison is not possible. Instead, in that case, emissions when utilising wastes were 'benchmarked' against emissions arising when utilising coal only.

1.3.3 Key technologies

There are a large number of technologies that could potentially have been considered in the study. As agreed with Defra, the following key technologies were included in the study:

- anaerobic digestion;
- autoclave;
- cement works;
- clinical waste incinerators;
- composting;
- gasification;
- pyrolysis;
- recycling;
- scrapyards; and
- small scale incineration.

Consideration was also given to Mechanical Biological Treatment as a discreet technology, whilst recognising that this technology is actually a combination of other technologies.

Within the 2005 report, comprehensive data were presented for landfill and Energy from Waste and these data are unlikely to have changed substantially since that report was published. However, particular data for these two technologies were also updated: data relating to non-routine emissions were reviewed for both technologies; and the previously available emissions data for Energy form Waste were updated to enhance this dataset where possible.

Emissions from Refuse Derived Fuel were also studied. Whilst RDF is not a technology in its own right, it was considered helpful to investigate whether operating a combustion plant utilising Refuse Derived Fuel was likely to substantially change the emissions from the plant.

In addition, a number of other processes were also considered, albeit on a much smaller basis. These included:

- underground disposal of hazardous wastes;
- hazardous waste landfill;
- inert waste landfills;
- waste transfer stations;
- hazardous waste transfer stations; and
- construction and demolition waste handling sites.

1.3.4 Context

Emissions from waste management facilities were placed into a UK-wide context using data obtained from the National Atmospheric Emissions Inventory (NAEI). The NAEI data is presented in terms of 'unit mass emission per year', and broken down into various sectors, including waste management. These data were used to provide context for the contribution of waste management in the UK to the total emissions of the key pollutants to air.

1.3.5 Routine operations

The presentation of data on emissions from facilities is a core aim of the report. The report focuses primarily on emissions to air, as these enter the environment directly (as opposed to emissions to water which are typically discharged to sewer for further treatment for example). However, data for water are also provided. During the study, with agreement from Defra, the decision was made that data relating to impacts on land and water due to use of residual materials (ie AD residues and compost) would not be included as these were considered indirect emissions.

Some technologies have more data available than others. For example, due to the large number of composting facilities and the maturity of this technology there are numerous data sources for compost plants. Conversely, for other technologies such as autoclaves, gasification and pyrolysis plants which are either experimental or have only a small number of operational facilities, there is a paucity of available data. Difficulty was also encountered in obtaining data from outside the UK which have not been published in peer reviewed press, for example emissions data recorded by regulatory bodies. Therefore whilst it is recognised that data exist, obtaining these data has in some cases not been possible.

In addition, the need to present emissions data in terms of grams emission per tonne of waste processed, to allow direct comparison between different technologies, limited the availability of data. In some cases, namely Energy from Waste and Anaerobic Digestion, it was possible to convert from emission concentrations to grams per tonne based on the throughput of waste. However, in other cases where emission concentrations were presented with no reference to the quantity of waste processed, calculation of emissions in grams per tonne of waste was not possible.

1.3.6 Non-routine operations

In addition to looking at emissions arising from waste management processes during normal operations, an attempt was also made to identify emissions that might arise when processes experience 'non-routine' events. These non-routine events included a wide range of possible situations from relatively minor deviations from normal operation resulting in small increases in emissions, through to large scale 'failures', such as fires.

Due to the nature of non-routine events these cannot be predicted and therefore only in certain circumstances is it possible to identify where variations in emissions occur as a result. An example of this would be the introduction of an atypical waste into an Energy from Waste plant, leading to a short term change in emissions which is detected by the Continuous Emissions Monitoring System (CEMS). However, in the event of a subsurface fire at a landfill or a fire at a composting facility, quantification of emissions is highly uncertain.

The report includes data that were identified for both emissions from non-routine events and also in terms of the types of non-routine events that may occur and their frequency. The data presented attempt to reflect general trends rather than set out detailed emissions data.

Several data sources were investigated, including records of non-routine events held by the Environment Agency and also reports of non-routine events as reported in literature, primarily the ENDS report. In addition, within the Environmental Permitting regime, some types of plants (primarily Energy from Waste plants and Clinical Waste Incinerators that are equipped with CEMS systems) are required to report non-routine events that lead to emissions exceeding emission limits. These are recorded by the Environment Agency and are available from the public register. These data have been interrogated to provide an indication of emissions during various non-routine events.

1.3.7 Research priorities

One of the key aims of the study was to identify where there were significant gaps in the understanding of emissions from waste management processes. These gaps were not necessarily simply where there were no data identified for a given process, but were also identified where there is substantial variation or uncertainties in the data identified. It is also important to understand that, where a 'data gap' was identified, this does not in any way imply that there is a risk associated with this gap, only that there was an identified need to improve understanding. On this basis, the 'data gaps' were based upon a number of factors:

- No data identified for an emissions that could, theoretically, be emitted in a concentration that may be of interest from a regulatory perspective;

- The data identified suggest that emissions are highly variable (orders of magnitude), or there is a high degree of uncertainty in the data set;

- A focus on processes that were considered more likely to be commonplace, now or in the near future; and

- Pollutants that are emerging as being of increasing interest in the future (for example specific size fractions of particulate matter).

The identification of research priorities was based on the data gaps, prioritised as discussed above, but also taking into account potential 'environmental impacts' (which in themselves were not a focus for the study). Research priorities are presented in the report as a matrix of emissions and waste technologies.

1.4 KEY FINDINGS

1.4.1 Overview

The study identified that there is a wide range of information available relating to emissions from waste management processes, for a large number of pollutants of interest. The quality of data, amount of data available and the variability of the 'numbers' is considerably different for the various technologies considered.

1.4.2 Data quality and quantity

With regard to the availability and quality of data, this largely reflected the number of operational facilities, and whether the facilities are required to undertake routine monitoring. Acknowledgment is made of the fact that, in some cases, the review did not consider all of the information likely to be available. Some data are difficult to obtain, and in some cases existing data demonstrated that there are large uncertainties or a high degree of consistency in which case it was considered that further data were unlikely to add to the value of the dataset to any great extent.

The data identified for Cement works, Clinical Waste Incinerators, Composting plants and Energy from Waste facilities were of good quality and a substantial amount was identified. For Anaerobic Digestion, autoclave, Mechanical Biological Treatment, recycling plants, scrapyards and small scale incineration there was only a limited amount of data identified and the data were of poor quality. However, for gasification and pyrolysis plants whilst there were only limited data identified, those that were identified were of good quality.

Whilst the study focussed mainly on single technologies, consideration was also given to other processes which may be of interest and for which emissions data were identified. These included Refuse Derived Fuel, which is not in itself a waste management process; underground disposal of hazardous

wastes; hazardous waste landfill; inert waste landfills; waste transfer stations; hazardous waste transfer stations; and construction and demolition waste handling sites. The availability of data for these processes was limited and in each case typically related to a single study; however these data were included for interest and to highlight research priorities.

1.4.3 Research priorities

When assessing the need for further research, the aim was deliberately to identify a small number of the highest priority research needs. The methodology used was therefore designed accordingly and the research needs were classified as 'high', 'medium' and 'low' priority, in order to assist Government to prioritise further research work. Of the waste management processes considered in the study, four were identified as having 'high' research priorities; these being composting, landfill, scrapyards, and construction and demolition sites. These are all technologies where: there are substantial variations in processes, scale and operations between sites; there may be limited or no containment and control of emissions to air; and, in the majority of cases, emission sources are open air.

Composting was identified as a technology where it would be beneficial to develop a better overall understanding of emissions. This was primarily as the data indicate that emissions are extremely variable for some pollutants. Pronounced variations were evident for plants of different designs and accepting different waste materials. Better understanding of emission of bioaerosols and particulate matter were identified as of particular interest. Defra is currently in the process of commissioning another project to monitor emissions of bioaerosols and odour from composting sites, and this, along with other ongoing research in the field, will help fill in this data gap. In addition, the evidence suggested that a better understanding of emission of ammonia, volatile organic compounds and particulate matter (as $PM_{2.5}$) would also be beneficial.

Landfill was also identified as a technology where the study identified that emissions can be highly variable between sites. Better understanding of emission of volatile organic compounds and bioaerosols were identified as of particular interest. In addition, the evidence suggested that a better understanding of emission of ammonia, polycyclic aromatic hydrocarbons and metals would also be beneficial.

Scrapyards were identified as a research priority as there is the potential for emissions to vary substantially between sites, and there is also a paucity of information available. The study identified specifically that additional understanding of emissions of volatile organic compounds, polycyclic aromatic hydrocarbons, particulate matter and dioxins and furans would be beneficial.

The small amount of information identified relating to construction and demolition sites suggested that there is the potential for these sites to be associated with substantial emissions of particulate matter. Due to a paucity

of information relating to these emissions, this was identified as a research priority.

Various research priorities were identified for the other technologies that were studied although these were not considered to be of 'high' priority. In summary, better understanding of the following emissions would be beneficial:

- Emissions of volatile organic compounds from anaerobic digestion;
- Overall emissions associated with autoclaving, and in particular volatile organic compounds and bioaerosols;
- Emissions of volatile organic compounds and $PM_{2.5}$ from cement plants;
- Emissions of volatile organic compounds from Energy from Waste plants;
- Improved understanding of all emissions from gasification/pyrolysis plans, specifically volatile organic compounds, polycyclic aromatic hydrocarbons and metals;
- Improved understanding of all emissions from Mechanical Biological Treatment plant, specifically emissions of bioaerosols; and
- Improved understanding of all emissions from the combustion of Refuse Derived Fuel.

1.4.4 Non-routine events and operations

Barriers to studying non-routine events and operations

An attempt was made within the study to identify non-routine events and operations, and where possible, to quantify the associated emissions. However, there are substantial barriers to doing this.

By their nature, non-routine events and operations are unplanned and therefore unless monitoring is undertaken as a matter of course, any changes in emissions will not be captured. Energy from Waste, Clinical Waste Incineration and Cement plants are all equipped with in-stack Continuous Emissions Monitoring Systems. Therefore, when non-routine operations occur within these combustion processes the subsequent changes in emissions are recorded, and indeed as part of the Environmental Permitting regulation for these facilities, these are reported to the Environment Agency. These data provide a useful insight into the types of events that can occur, and the resulting change in emissions which occur as a result. However, in general, other processes are not equipped with Continuous Emissions Monitoring Systems and the monitoring systems that are employed are inappropriate for

the quantification of emissions during non-routine operations, in particular short term events. One exception identified was that of landfill fires; in that case due to the fact that fires can burn for a period of days, there is an opportunity for undertaking monitoring.

In addition, there are substantial issues around ensuring that those events which are reported are representative of the type of event that can occur for such a process, and that they capture all pertinent events. Again, in the case of processes such as Energy from Waste, Clinical Waste Incineration and Cement plants, where non-routine events are recorded and reported when associated with elevated emissions, there is high confidence that most of, if not all, relevant events are captured. However, for many other waste management technologies there is no statutory requirement, and in many cases no need, to formally report non-routine operations that lead to changes in emissions for all but the most serious non-routine operations. Therefore in these cases, the numbers of non-routine operations resulting in increases in emissions are likely to be somewhat underestimated, and certainly there is no data relating to emissions.

In the study, therefore, for the small number of cases where it was possible to quantify changes in emissions associated with specific non-routine operations this was done and the data presented. In other cases, the study was limited to presentation of examples of the types of events that may occur, for example based upon occasional events reported in the press. Whilst this approach has important limitations, the intention was to provide some indication of possible non-routine operations and possible changes in emissions.

Summary of findings

For most of the waste management technologies considered, examples of non-routine emissions were identified. In the case of Energy from Waste, Clinical Waste Incineration and Cement plants data relating to changes in emissions during certain types of non-routine operations were identified. Examples of this include: failure of abatement plant; and introduction of atypical wastes (in Energy from Waste plants). In these cases it was possible to identify the specific event that led to the increase in emissions, the magnitude of the change and the duration of the increased emission.

In the case of landfill sites, several non-routine events were identified that have the potential to result in elevated emissions. These include fires, failure of the landfill gas collection system, receipt of atypical loads, failure of leachate containment, and failure of gas combustion equipment. The relatively large numbers of types of incidents, and numbers of recorded incidents is likely to be, to some degree, associated with the large numbers of operational landfill sites.

In the case of composting plants, there were also several different types of non-routine events identified that could potentially lead to elevated emissions. Examples include, fires, failure of abatement plant, failure of equipment and

development of anaerobic conditions. Of these events, those resulting in increased emissions of odour were by far the most common identified.

For the remaining processes that were studied, there were very few cases of non-routine operations or events being recorded, and those that were are considered to be exceptional. This does not necessarily mean that non-routine operations do not or cannot occur, merely that within the study, little or no information on non-routine events was identified.

1.5 SUMMARY

The study identified that there is a wealth of data available relating to emissions from waste management technologies but that there is, understandably, much greater information available for those technologies that are more mature and widespread. The study also identified that for some processes there is little variation in emissions between facilities, whilst for others there is a very large variation between processes and when processing different waste types.

The highest research priorities identified from the study, were for those technologies which are undertaken in the open and which are therefore largely uncontained as far as emissions to air are concerned.

The study identified that the records of non-routine events and operations that lead to increases in emissions are far more complete for some technologies than others. On this basis, whilst it was not possible to present a meaningful comparison of different technologies, useful information was presented on emissions arising during non-routine operations for some technologies, and also the types of non-routine events and operations that occur for others.