Review of Environmental and Health Effects of Waste Management:

Municipal Solid Waste and Similar Wastes

Extended Summary

May 2004

ENVIROS

THE UNIVERSITY OF BIRMINGHAM

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Foreword by Minister of State, Environment & Agri-Environment

The Prime Minister's Strategy Unit, in its report *"Waste not, Want not"* recommended that an independent body should bring together the literature and evidence on the relative health and environmental effects of all the different waste management options; relative both to each other and to other activities affecting health and the environment. Defra commissioned this report in response to that recommendation.

The report examines the waste management options for treating municipal solid and similar waste. It focuses, as Defra requested, on the principal types of facilities that are currently used for dealing with such waste in the UK and in Europe and on what the currently available scientific evidence can tell us about their environmental and health effects.

It is a very comprehensive report and brings together, for the first time, a wealth of evidence which allows us to consider the health and environmental impacts of waste management on the basis of all available information.

The report has been peer reviewed by the Royal Society and I am grateful to Prof. Howard Dalton, Defra's Chief Scientific Advisor, for advising me on the scientific analyses.

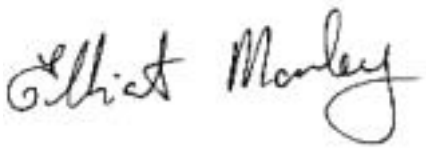
I am particularly encouraged by the report's conclusion that, on the evidence from studies so far, the treatment of municipal solid waste has at most a minor effect on health in this country particularly when compared with other health risks associated with ordinary day to day living. The evidence on environmental effects is limited, but such as there is does not appear to suggest adverse environmental effects of waste management, other than those we know about and are already addressing, such as methane emissions from landfill.

The report rightly recognises that there is more that we can and should still learn and we will be addressing the need and priorities for further research through our waste research strategy this summer. The search for knowledge is never complete and this report usefully identifies areas of research that we will be taking forward as part of our continual efforts to refine the evidence base for policy making.

I believe that this report does give us sufficient confidence in our current policies for local authorities to press ahead urgently with the task of approving planning applications for new waste management facilities. Among the other conclusions to be drawn, the report shows that risks to human health from incineration are small in comparison with other known risks. We must acknowledge the role of incineration with energy recovery as a sustainable waste management option although the priority must be waste minimisation, reuse and recycling. Incineration is an option for dealing with the residual waste that will still be left even after achieving the much higher levels of recycling and reuse we are aiming for and to help absorb the diversion of municipal waste from landfill which we are required to make under the Landfill Directive.

Foreword

We must manage the growing amount of waste we produce. We will do this by basing our policies on the best available scientific evidence and on an assessment of the comparative risks. We will continue to develop our scientific knowledge to support our policies. This report is a helpful contribution to that process.



Elliot Morley
Minister of State for Environment & Agri-Environment

Foreword by Defra Chief Scientific Adviser

Ministers asked for my assessment of this report in my role as Chief Scientific Adviser to the Department. This Foreword is the advice I have given in light of that request.

This is a timely and useful report, which for the first time provides Government with a critical assessment of the available peer-reviewed scientific literature on the health and environmental effects of options for managing municipal solid waste. I am grateful to the authors, Enviros Consulting Ltd., Professor Harrison, and their colleagues, for their comprehensive and thorough review, and for approaching a difficult task in a positive and imaginative way. I am also very appreciative of the work done by the Royal Society in providing a detailed critique which has been reflected in finalising this report. The Royal Society's working group provided valuable comments on the emerging report. Their statement of March 2004 reflects the extent to which their formal critique of the full draft of November 2003 has contributed in shaping the final version of the review. (These are reproduced at Appendix 4.)

The review and insights of the Royal Society's working group have been of great assistance in preparing my advice to Ministers on the science to support waste management policy. Particularly helpful in this regard is the critical assessment of the quality of the scientific evidence on each of the issues through the use of a 'reliability index', a feature that other similar assessments might adopt to advantage.

The review has concluded that the effects on health from emissions from incineration, largely to air, are likely to be small in relation to other known risks to health. I have confidence in this conclusion, particularly bearing in mind the fact that the current generation of municipal solid waste incinerators have to comply with much more stringent emission standards than those which formed the basis for the majority of studies of health effects in the literature. This does not mean that we can afford to be complacent; rigorous enforcement will be crucial to ensure that the new emission standards are not exceeded, and that non-standard operating conditions, as noted by the Royal Society, do not lead to levels of emission which would give rise to concern.

The review has also addressed the effects on the wider environment. The most important in this context is the contribution that landfill emissions make to emissions of methane, a powerful greenhouse gas. The review has also noted that odours from landfill can be important, and that measures to capture and use landfill gas could alleviate both of these potential problems. The review reported little existing evidence of other environmental effects due to waste management.

The contributions of municipal solid waste to air emissions of methane (27% of UK total) and cadmium (about 10% of UK total) are well known to arise mostly from landfill. This is one of the reasons why government policy is moving away from the landfill waste option. With these exceptions, management of municipal solid waste accounts for less than 2.5% of all other emissions for which data are available (including carbon dioxide and toxic gases). These conclusions mean that the overall scale of direct effects of releases to air from waste management practices is relatively small compared with emissions from other sectors such as transport.

Foreword

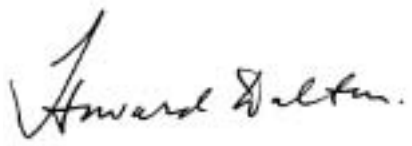
I am nevertheless aware that, since the review was first and foremost a review of the existing literature, coverage will be limited by the availability of evidence, so some areas of the science will be analysed in more depth than others. Consequently there will be gaps and uncertainties in the evidence base.

Areas where there is less work and the science is less certain include releases to soil and water and releases from composting, or other forms of waste management like mechanical biological treatment or anaerobic digestion. One other important study reported an association between birth defects and proximity to landfill sites. The authors of that study were clear, however, that the association reported in this single study does not demonstrate a causal relationship, and the current review reflects this. It would be desirable if further studies could be carried out to identify the non-waste related factors which may influence this association.

In order to reduce, or remove these uncertainties, and to fill gaps highlighted by the review as missing from the current literature, we will need to undertake further research. The issues suggested by the review will be included in consideration of priorities as the waste research strategy is developed, with interested stakeholders, and particularly with the Department of Health.

The Royal Society has highlighted the advantages offered by Life Cycle Analysis in extending the range and scope of comparative analyses available. Life Cycle Analysis (as advocated in Defra's Waste Strategy 2000, and used by the Environment Agency in their WISARD waste management software) is of particular relevance in recycling, and should be incorporated in future research design on this issue.

In conclusion, I welcome this report. Not collecting or managing waste is not an option. The formulation of policy on the management and disposal of waste is an important area of Defra's work. This report helps decision makers by bringing together and analysing the existing body of waste management research.



Professor Howard Dalton FRS

Introduction

This document

DEFRA (The Department for Environment, Food and Rural Affairs) commissioned Enviros Consulting Ltd and Birmingham University to draw together the available information on the environmental and health effects of managing municipal solid waste.

This followed a recommendation in the Prime Minister's Strategy Unit report "*Waste not, Want not: A strategy for tackling the waste problem in England*" (November 2002), and an announcement in the Pre-Budget Report of 2002 that the Government would commission a review of the environmental and health effects of waste management and disposal options.

This document is an extended summary of the report *"Review of Environmental and Health Effects of Waste Management: Municipal Solid Waste and Similar Wastes"*. The main report can be obtained from www.defra.gov.uk/environment/waste. The study considers municipal solid waste and similar wastes, and will be followed by a further study of other wastes.

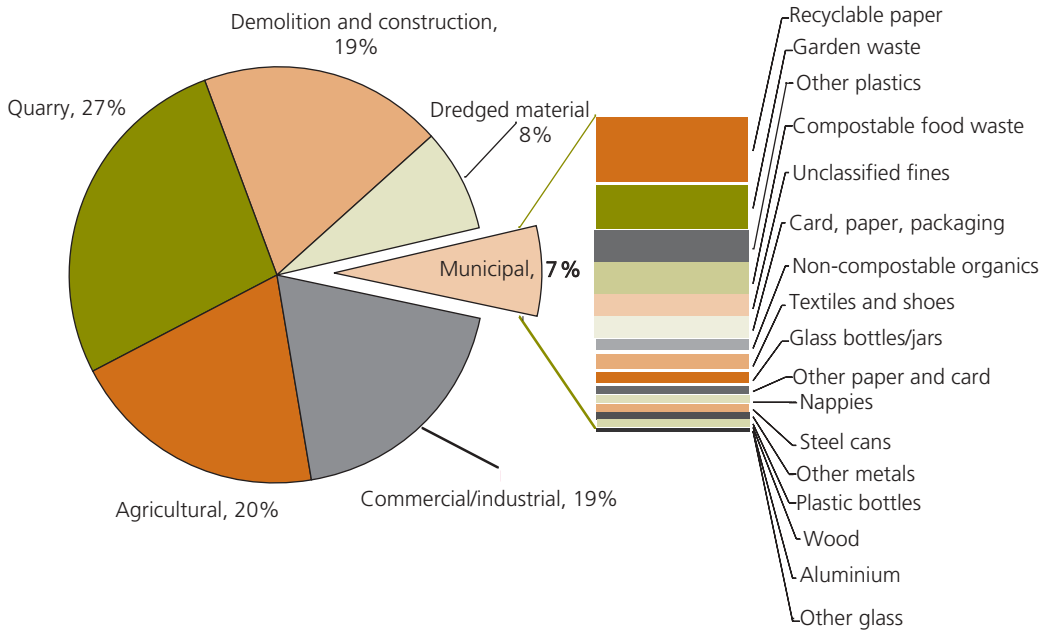
An introduction to waste management in the UK

What waste is, and where it comes from

In the UK we produce about 430 million tonnes of waste a year. That's enough waste to fill the Albert Hall in London every hour. Of this, about 7% (29 million tonnes) is municipal solid waste. Municipal solid waste is the waste materials generated in the home, and by schools, shops, and small businesses – any waste collected by the local authority (or companies working for the local authority). Because of this, municipal solid waste contains a wide variety of materials, reflecting the variety of things that we buy, use and then throw away. Much commercial waste, and some industrial waste is similar to municipal solid waste, so much of the information in this report will apply to the management of commercial and industrial waste streams. Figure 1 shows the sources of waste in the UK, and the materials that municipal solid waste is made up from.

Waste is an inevitable by-product of our use of natural resources. The amount and make-up of waste in any given area depends on factors such as the local population density, economic prosperity, time of year, type of housing and whether there are local waste minimisation initiatives such as home composting.

Figure 1: Waste in the UK



And where it goes to – disposing of municipal solid waste

About three quarters of the UK's municipal solid waste is disposed of directly to landfill. Reuse and recycling (including composting) account for a further 13% of municipal solid waste. The remainder is pre-treated, mostly by incineration (approximately 9% of municipal solid waste). The remaining 1% is pre-treated using a variety of new or specialist methods which include gasification/pyrolysis; mechanical biological treatment (MBT); and anaerobic digestion. In this report, we consider the potential effects of all these waste management options, as well as the potential effects of transporting over 80,000 tonnes of municipal solid waste a day.

Ways of dealing with municipal solid waste considered in this report

Reuse and recycling is where waste materials are put back into the raw product stream, either as base material, as with glass, plastics and paper, or as reusable product as with returnable milk bottles. This study looked at the facilities where sorting of materials to be recycled takes place. However, in this study, we did not look at industrial waste recycling processes themselves. The recovery of materials in this way will reduce the need to use natural resources directly, and may reduce emissions from extraction and processing of raw materials. On the other hand, there could be environmental or health effects from reprocessing materials which have been taken out of the waste stream. These could offset the benefits of recycling to some extent.

Composting uses micro-organisms to break down organic waste in the presence of air, usually to produce compost suitable for adding to soil or as a pre-treatment step. Composting is usually carried out on pre-sorted municipal solid waste or specific organic waste, for example wood chippings, grass cuttings or kitchen waste. Composting can be carried out in the open air (this is known as "windrow" composting). Increasingly, in-vessel systems are being used. These enable the composting process to be automated and any emissions to be more readily controlled.

Mechanical Biological Treatment is a composite process involving a mix of sorting; separation; cutting or grinding the waste into smaller pieces; and composting, The residual materials may be used as compost, incinerated (with energy recovery) or landfilled.

Anaerobic digestion is the decomposition of organic waste in an oxygen-free atmosphere. This produces gas comprising mainly methane and carbon dioxide, which is burnt for electricity generation. The digested waste material can be composted and spread onto land.

Gasification is a process in which a portion of the waste is burnt in a reactor at high temperature. The majority of the organic material present in the waste is converted into carbon monoxide, hydrogen and methane. Pyrolysis involves indirect heating of the waste in an oxygen free atmosphere. This turns organic materials into simple gases, oils and char. The char produced in both cases can be further reacted with air and steam to produce hydrogen and carbon monoxide. Finally the gases are burnt to produce heat, which is usually used to produce electricity. The remaining ash can be re-used or sent to landfill. There is one UK process operating using this approach, which uses a combination of both pyrolysis and gasification.

Incineration involves the burning of waste to reduce the volume of solids (typically by 70%.) and generate heat and/or electricity. The resulting ash can again be re-used or sent to landfill. The residue from air pollution control systems used at waste incineration processes is a fine ash, typically about 4% of the weight of waste processed. This is a hazardous material, and normally needs to be disposed of at a landfill licensed to accept this kind of waste. The use of energy generated from incineration will reduce the need to generate energy from other sources.

Landfill is a specially engineered area of land where waste is deposited. Once an individual section of the landfill is full, it is sealed with a permanent cap. The biodegradable part of the waste then decomposes and reduces in volume. Much of the non-biodegradable content of municipal solid waste is stable, and is not released from landfill sites at discernible rates. The gas produced by decomposition of municipal solid waste is increasingly used to generate electricity – the extent of collection and burning of landfill gas varies from site to site. Landfill will probably always be needed for the final disposal of unusable residues.

Some of these options result in the generation of electricity. If this occurs, then we do not need to generate so much electricity by other methods. This would result in an overall decrease in emissions from power stations which would otherwise occur.

Waste transportation Municipal solid waste needs to be transported from where it is produced to a transfer station or treatment/disposal facility. The majority of municipal waste is transported by road. This makes a contribution to emissions from, and effects of transport in the UK as a whole.

In this study, we looked at the effects of the particular facilities themselves. Indirect effects (like the benefits of avoiding use of raw materials by recycling) were not part of our remit.

Waste management at a time of change

Municipal solid waste management in the UK is currently in a period of change. There are pressures to move away from traditional disposal methods, while new technology is increasing the alternatives for waste disposal. These changes are brought about by initiatives such as:

- The introduction of the landfill tax, which is increasing the cost of disposal to landfill;
- The European Landfill Directive, which harmonises and tightens landfill standards throughout the European Union, and also requires a progressive reduction in the amount of biodegradable municipal waste disposed of to landfill. This Directive also means that hazardous wastes will need to be disposed of separately from municipal solid waste and similar wastes;
- The European Waste Incineration Directive, which is resulting in tighter emission limits and improved technology on incinerators;
- Policy measures to reduce emissions of gases responsible for 'global warming' are making landfill and incineration of municipal solid waste and similar wastes less attractive.

Worries about the health effects of waste management

A few individual sites have been the focus of concerns about the possibility of health effects on people living close to these sites. A lot of detailed research has been carried out, both at these specific sites and nationally, to investigate whether waste management operations do in fact have any adverse health effects:

- Landfill sites have been investigated as the possible cause of birth defects, cancers and respiratory illnesses including asthma;
- Incinerators have been investigated as to possible increases in cancer, birth defects and respiratory illnesses including asthma. Other studies have particularly concentrated on emissions of dioxins;
- Composting and Materials Recycling Facilities (MRFs) have been investigated for possible exposures to micro-organisms and odours, and lung diseases like bronchitis.

Worries about the environmental effects of waste management

There is also concern about the environmental effects of facilities which deal with municipal solid waste. For example, emissions from municipal solid waste processes might affect acid rain or global warming. Plant life near landfill sites might be affected by landfill gas or water contaminated by waste, if these are allowed to escape from a site. Odours or noise from municipal solid waste facilities are occasionally a problem. We have investigated whether there is scientific evidence for the occurrence of these environmental effects.

How is the potential for health effects investigated?

The possible health effects of waste management operations have been investigated two main ways:

- Epidemiological studies – these are studies of the distribution (or pattern) and determinants (or causes) of disease in human populations.
- Emissions based studies – which measure emissions being released into the environment from one or more sources. Based on this, human exposures to emitted substances can be estimated, and the risks to human health can be assessed.

What's different about this report?

Research into waste management and its environmental and health effects is an established area of science. There is no lack of research reports and reviews, although it can be hard to find information of good enough quality to rely on. The available research includes reports from the Environment Agency, the UK Government, a recent study by the Irish Government, and work by the American Agency for Toxic Substances and Disease Registry, Greenpeace, and other organisations. These reviews discuss and draw together the conclusions of other studies but don't usually put numbers on possible health effects or put the conclusions into context.

This report is different because we have set out to quantify, where possible, the potential health effects of waste management. We have also provided a detailed set of data on emissions. We have indicated how reliable (or otherwise) the information is. We have set out comparisons between different waste management options. We have also provided information to allow all of this information to be set in the context of other activities like traffic, other industry, and household activities such as cooking.

The report does not give the whole picture on its own. It needs to be read alongside other information – for example, studies of environmental effects associated with the whole lifecycle of wastes; information on the monetary costs of emissions and environmental effects; and information on the local surroundings of a particular facility.

The approach used

Literature review

We carried out an extensive search and review of the available literature relating to waste management activities. Over 600 papers covering a wide range of sources of information were included: reviewed journals (i.e. scientific texts), Government publications, Environment Agency publications, publications from other institutions (e.g. Greenpeace, and the National Society for Clean Air and Environmental Protection), and information from waste management operators. Most of the information from operators was drawn from their submissions to the Environment Agency. The literature review covered the following areas:

- Studies, reports and information from municipal solid waste facility operators containing emissions data;
- Studies and reports investigating the occurrence of health effects near municipal solid waste management facilities;
- Studies and reports investigating environmental impacts close to municipal solid waste management facilities;

We rated the quality of the information on a scale from poor, through moderate and good, to very good. To do this, we have considered points like how easy it would be to cross check the information, how many measurements were taken, and how reliable the measurement methods were.

Comparing emissions from different municipal solid waste management facilities

We found a large quantity of information regarding emissions of materials from waste management facilities. Most of this was not published in scientific papers, but was provided by operators of waste management facilities, or regulators like the Environment Agency. Some was of good quality, whilst other data were of moderate or even poor quality. Information considered to be of poor quality was only presented where no better information was available, and we have drawn attention to areas where better quality information would be useful. This information was analysed to find out the likely emissions of different pollutants from waste management operations. The aim of the data analysis was to find a figure for 'emission of pollutant x per tonne of waste processed' for the different waste management options.

We found most information for emissions to air. There was less information available on emissions to land, water or other waste management facilities. This does not necessarily mean that the air emissions are more important instead it suggests that more research into other emissions could be helpful.

We looked at emissions under normal operating conditions. Occassionally the normal operation of waste management facilities is disrupted in some way. For example, emissions from a waste incinerator sometimes exceed the limits set in the operating licence, or the gas control system at a landfill site might fail from time to time, resulting in an increase in emissions of unburnt gas. We considered the kind of incidents which occur at different waste management facilities, and highlighted the incidents which are of greatest concern.

In some cases, we provided estimates of annual emissions from a particular waste management facility, and we were also able to estimate the total annual emissions from managing municipal solid waste in England and Wales.

Information on emissions is useful for comparing different waste management options, but does not allow us to identify the health effects of these emissions. To do this, we need to investigate the exposure of local people to the substances emitted. This is described in the next section.

Evaluating the health effects

We looked at whether the evidence showed that waste management operations might cause health effects for people living nearby. Where the literature review showed that there might be a link between waste management operations and health effects, we calculated what this might mean for local populations. We studied this in two ways.

Firstly, we considered whether the results of epidemiological studies could be used to quantify any extra health effects that might arise in populations living close to municipal solid waste management facilities, compared to those that would arise if the municipal solid waste facility was not there. Secondly, we estimated the health effects caused by emissions of particular pollutants to the air, based on information on the health effects of increasing levels of these pollutants. We could not do a similar calculation for emissions to water or land, because it is not possible to make similar estimates of public exposure to these pollutants.

Where the information permitted, the health effects were calculated on a "per tonne of waste processed" basis. This enabled us to compare the health impacts of different waste management options.

Putting things in context

Waste management operations are only one of many sources of emissions and health/ environmental effects. We therefore also looked at other sources of emissions such as road traffic, other industries, and domestic activities. This enabled us to put the emissions from waste management facilities into context with other sources of emissions. From this, we can assess the relative importance of waste management as a source of these substances.

We also looked at the estimated health effects of waste management in the context of other issues which affect health. This included the health effects of air pollution, passive smoking, road traffic accidents, and accidents in the home or at work.

How have we checked the quality of the study?

In order to make sure that the report was as complete as possible, and that the conclusions were supported by the information, DEFRA asked the Royal Society to look at the report in detail.

The review was written by:

Enviros Consulting Ltd.

Mark Broomfield, Jonathan Davies, Nigel Bellamy, Richard Carpenter, Chris Hazell, David Sellwood, Paul Frith and the late Mick Morrey.

University of Birmingham

Roy Harrison, Steve Thomas

Other contributors

Toni Gladding (Open University), Meg Postle (RPA Ltd.), Maggie Thurgood

Main report

This summary can be freely copied. The main report and summary can be obtained from:www.defra.gov.uk/environment/waste www.enviros.com

The main findings

This section summarises the main findings of the report.

What are the main emissions from municipal solid waste?

The main emissions from waste management operations are summarised below. A more detailed breakdown is provided in section 3. We found most information for emissions to air. There was less information available on emissions to land, water or other waste management facilities. This does not necessarily mean that the air emissions are more important instead it suggests that more research into other emissions could be helpful.

- Methane and carbon dioxide are the two emitted substances which may significantly influence global warming.

  In the UK nearly 150 million tonnes (MT) of CO_2 is released every year. Management of municipal solid waste accounted for 3.6 MT (2.4% of the national total). Other important contributors are electricity generation (42 MT; 28.5% of the national total); and transport (21% of the national total). These figures are of moderate or good quality.

  Methane has a global warming effect which is over 20 times more powerful than carbon dioxide. In the UK about 2.4 MT of methane is released every year. Emissions from municipal solid waste in landfill sites account for 0.7 MT (27% of the national total). Although these figures are of moderate or poor quality. Another important contributor is agriculture, which accounts for an estimated 1.0 MT (about 40% of the UK total)

- Benzene is a substance of concern because it can cause cancer. We found that less than 0.02% of UK emissions are due to municipal solid waste operations (this figure is of moderate quality). Transport is the main source of benzene, accounting for 47% of UK emissions.

- A lot of people are concerned about emissions of dioxins and furans (often referred to as just "dioxins"). The developing reproductive system of male offspring seems to be particularly sensitive to exposure to dioxins before birth. Dioxins are associated with other developmental and reproductive effects, and the immune system is also potentially sensitive. UK expert committees regard dioxins as a probable human carcinogen (that is, it can probably cause cancer in humans). We found that dealing with municipal solid waste accounts for only about 1% of UK emissions of dioxins, shared approximately equally between incineration and emissions from burning landfill gas. This figure is of poor quality because of uncertainty over dioxin emissions from other sources. Domestic sources such as cooking and burning coal for heating are the UK's single largest source of dioxins, accounting for about 18% of emissions. Transport accounts for about 3% and electricity generation about 4% of the UK total. A number of other sources contribute to emissions of dioxins to a similar or greater extent: accidental vehicle fires; fireworks and bonfires; small-scale waste burning (for example on building sites); incineration of other wastes; and the iron and steel industry.

- Nitrogen dioxide is a substance of concern, particularly for air quality in urban areas. Emissions of oxides of nitrogen also contribute to acid rain, and excessive levels of nitrogen which can be harmful to some sensitive habitats. Dealing with municipal solid waste results in emissions of about 10,000 tonnes per year of oxides of nitrogen (which form nitrogen dioxide in the atmosphere). This is less than 1% of the UK total – the main contributors are electricity

generation (24%) and road traffic (42%) (those values are of moderate quality). Emissions of oxides of nitrogen and other substances from incineration of municipal solid waste are the most tightly controlled of all waste management processes.

- Metals emitted to the air have a range of possible health effects. Dealing with municipal solid waste accounts for about one tenth of UK emissions of cadmium (a substance associated with cancer of the lungs, throat and prostate, reproductive effects and kidney disease). Almost all of the cadmium emitted from facilities dealing with MSW comes from landfill sites. Municipal solid waste accounts for lower proportions of UK emissions of other substances. The iron and steel industry is the main source of emissions of most heavy metals (for example mercury, arsenic, lead, cadmium). The numerical values are of moderate or poor quality. Other important sources include:
  - lead emissions from non-ferrous metals processing;
  - burning coal to produce electricity and heat in industrial facilities, which is an important source of arsenic emissions;
  - road traffic, which is an important source of mercury. The manufacture of chlorine from mercury cells, non-ferrous metal production and coal combustion are also important sources.
- Although there was less information available we also studied emissions to groundwater and surface water. The substances we looked at included nitrogen (which can promote the growth of unwanted algae); organo-tin compounds (which can affect fish and shellfish), phosphates, pentachlorophenol, copper, tin and lead. Information on these emissions is less widely available, and our estimates in this area were only of poor quality. Bearing this in mind, the rough estimates of emissions of substances which might be of concern are all a very small proportion of the national total. Releases to groundwater and surface water, unlike releases to the air, do not necessarily result in human exposure because mains water is treated before supply. Mains water has to comply with strict safety standards.

Some facilities (anaerobic digestion, pyrolysis/gasification, incineration and landfill) result in the generation of electricity. This means that we would avoid the need to generate electricity in other ways – for example, from burning coal, gas or oil, or from nuclear energy.

Health effects linked to municipal solid waste

Increased emissions under non-standard operating conditions could be a concern for open windrow composting, if the waste is not handled properly. Disposal of ash from incinerators needs to be carefully managed and landfills can give rise to emissions to water, land or air unless properly managed.

For most of the municipal solid waste facilities studied, we found that health effects in people living near waste management facilities were either generally not apparent, or the evidence was not consistent or convincing. However, a few aspects of waste management have been linked to health effects in local people. These are discussed below, followed by a discussion of the areas where no health effects have been found.

The main findings

Where there might be health effects

- A detailed study of landfill sites has identified a possible link between living close to a landfill site, and the occurrence of some birth defects. The study also considered the occurrence of unusually low birth weight. This study was not able to say whether the associations are causal, or whether they might be reflecting other factors which the study could not address fully. The observation is a small increase in the risk of a birth defect happening in babies born to families living near landfill sites. The increase is much smaller than other factors which influence the likelihood of birth defects, and the numerical results cannot at present be reliably used.
- A recent study undertaken at residential areas in close proximity to a commercial composting plant looked at the incidence of bronchitis and minor ailments in people living in this area. The study showed that there might be a link between emissions from the facility and these health effects in residents living nearby.

These health effects are discussed in more detail in Chapter 4.

Where investigations have been carried out but no health effects have been found

The health effects of some waste management facilities have been investigated in detail, in response to public concerns.

- The review did not find a link between the current generation of municipal solid waste incinerators and health effects. Adverse health effects have been observed in populations living around older, more polluting incinerators and industrial areas. However, the current generation of waste incinerators result in much lower levels of exposure to pollutants. We considered cancers, respiratory diseases and birth defects, but found no evidence for a link between the incidence of disease and the current generation of incinerators.
- A detailed UK study was carried out to investigate whether there is any indication that living close to landfill sites results in an increase in the occurrence of cancer. This study did not detect an increase in the occurrence of cancer.
- Studies have been carried out to investigate the existence of a link between composting facilities and the occurrence of cancers and asthma. No link has been identified.

Thus the studies suggest that if the operation of these facilities does have any effect on the health outcomes which have been investigated, any effect is very small – smaller than many other influences on these health outcomes.

What are the main environmental effects

The most important environmental impact reported in scientific research is the effect on global warming of emissions of greenhouse gases (most importantly, methane) from landfill of municipal solid waste. Methane is generated at all landfill sites accepting municipal solid waste, and the contribution of methane emitted from landfills to global warming is important. As a result, alternatives to landfill for municipal solid waste are often viewed as having a positive effect on

global warming by reducing the need to landfill biodegradable waste which generates methane. As the Landfill Directive is implemented, the amount of biodegradable waste being landfilled will reduce. Collection and combustion of landfill gas will also become much more widespread, although it is never possible to collect all the methane generated at a landfill site.

Some of the waste management operations involve heating or burning municipal solid waste (for example, incineration, gasification/pyrolysis, anaerobic digestion and the burning of collected landfill gas). These could have an effect on local air quality. For example, Mercury emissions from municipal solid waste incinerators were found to contribute 20% of the overall background mercury concentration at locations surrounding the incinerator.

Emissions of dioxins from municipal solid waste incinerators can increase levels of dioxins in soil, although the present generation of incinerators release much smaller amounts of dioxins than was the case five or ten years ago. Dioxins from an incinerator in an industrial environment will only slightly increase the total deposition of dioxins. We found that an incinerator located in a relatively clean rural environment could significantly increase the dioxin deposition above the much lower background level. Even then, the increase would only affect the immediate vicinity of the plant, and would not be expected to be a concern with regard to health. Emissions from municipal solid waste incinerators account for less than 1% of the dioxins experienced by members of the public.

Areas where we need more information

During the course of the project, we found several areas where potentially useful information was lacking, or was less than ideal as a basis for waste management policy. The most important areas which need to be studied are:

- Monitoring levels of pollutants emitted from landfill sites in communities located near to landfill sites, where this is not already carried out as part of regulatory monitoring;
- Studying how much particulate matter, micro-organisms, organic chemicals and methane is released from composting of municipal solid waste;
- Measuring emissions of micro-organisms and fungal spores from all forms of municipal solid waste management;
- Looking at what and how much is emitted to air, to sewer and in solid residues from processes which are not yet widely applied to municipal solid waste in this country – mechanical biological treatment, and anaerobic digestion.

Information on emissions

What substances did we look at?

Although there are hundreds of substances emitted during waste management operations, most of these are released in very small amounts which, as far as is known, are harmless. We concentrated on substances of concern, and those which are released in large quantities from the management of municipal solid waste. We identified substances for consideration in the assessment of emissions to air from the European directive on waste incineration, and research into the trace constituents of gas generated from decomposition of waste in landfill sites. We identified substances for consideration in the assessment of emissions to water/groundwater from research into emissions to water from landfill sites and substances identified in the waste incineration directive. In the case of solid residues, a more limited range of information was available, and so we provided information on all the substances covered in recent relevant research. We found that a useful range of information was available on the contents of ash from municipal solid waste incineration.

Some of the substances considered are produced or released when waste is burned, some are already in the waste and are emitted when waste is handled, and others are emitted by leaching into water which is then treated and discharged. All the substances that were considered in the review are listed below, with an indication of which municipal solid waste management processes might generate them.

Emissions to air considered in the study							
	C	**M**	**A**	**P**	**I**	**L**	**T**
Carbon Dioxide	✔	✔			✔	✔	✔
Dioxins and Furans		✔		✔	✔	✔	✔
Hydrogen Chloride		✔	✔	✔	✔	✔	
Hydrogen Fluoride		✔	✔	✔	✔	✔	
Individual volatile organic compounds: benzene, chlorobenzene, chloroethane, chloroethene, 1,1-dichloroethane tetrachloroethene	✔		✔			✔	✔
Metals: arsenic, cadmium, mercury, nickel			✔	✔	✔	✔	
Methane	✔	✔	✔	✔	✔	✔	
Nitrogen Oxides		✔	✔	✔	✔	✔	✔
Particulate Matter	✔		✔	✔	✔	✔	✔
Polychlorinated Biphenyls					✔		
Sulphur Dioxide		✔	✔	✔	✔	✔	✔
Total Volatile Organic Compounds		✔		✔	✔	✔	✔
C: Composting; M: MBT; A: Anaerobic digestion; P: Gasification/pyrolysis; I: Incineration; L: Landfill; T: Transport							

Substances in solid residues (reused or disposed of) considered in the study															
	C	M	A	P	I	L	T		C	M	A	P	I	L	T
Aluminium				✔	✔			Lead	✔		✔	✔	✔		
Ammonium	✔			✔				Magnesium	✔				✔		
Antimony					✔			Manganese					✔		
Arsenic	✔				✔			Mercury	✔		✔		✔		
Barium					✔			Nickel	✔		✔	✔	✔		
Cadmium	✔		✔	✔	✔			Phenol				✔			
Calcium					✔			Potassium					✔		
Carbonate					✔			Sodium					✔		
Chlorine				✔	✔			Sulphate				✔	✔		
Chromium	✔		✔	✔	✔			Sulphite					✔		
Cobalt					✔			Tin					✔		
Copper	✔		✔	✔	✔			Titanium					✔		
Dioxins and Furans	✔				✔			Vanadium					✔		
Fluoride					✔			Zinc	✔		✔	✔	✔		
Iron	✔				✔										

Emissions to sewer, groundwater or surface water considered in the study															
	C	M	A	P	I	L	T		C	M	A	P	I	L	T
Aniline						✔		Methyl chlorophenoxy acetic acid						✔	
Arsenic					✔	✔		Methyl tertiary butyl ether						✔	
Biphenyl						✔		Naphthalene						✔	
Cadmium	✔				✔	✔		Nickel					✔	✔	
Chloride	✔				✔	✔		Nitrogen		✔	✔			✔	
Chromium	✔				✔	✔		Nonyl phenol						✔	
Copper	✔				✔	✔		Organo-tin						✔	
Cyanide	✔					✔		Pentachlorophenol						✔	
Di (2-ethyl hexyl) phthalate						✔		Phenols	✔					✔	
Dichloromethane						✔		Phosphorus						✔	
Ethylbenzene						✔		Polycyclic aromatic hydrocarbons						✔	
Fluoride						✔		Suspended solids	✔					✔	
Lead	✔				✔	✔		Toluene						✔	
Mecoprop						✔		Xylene						✔	
Mercury	✔				✔	✔		Zinc	✔				✔	✔	

What are the main emissions?

We found most information for emissions to air, although this does not mean that emissions to surface water or groundwater are less important – simply that there is less information on emissions to surface water and groundwater.

Emissions to air could be broken down into substances released because they are in the waste or produced during its decomposition (examples include methane, volatile organic compounds, and metals), and substances resulting from burning waste or gases derived from waste (for example, carbon monoxide, oxides of nitrogen, and sulphur dioxide). Some substances can arise from both kinds of source – for example, dioxins and furans and particulate matter.

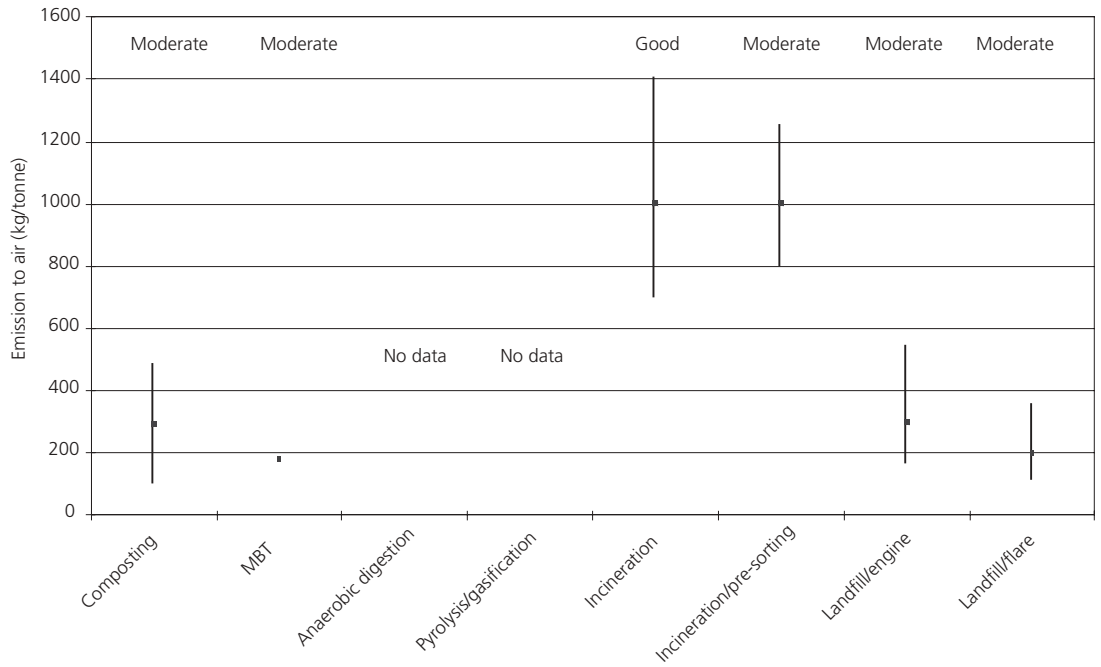
Emissions to water could take place in a number of ways, mostly from landfill. Water already in the wastes, or rainwater falling onto a landfill, acquires ("leaches") contaminants from the wastes and is known as "leachate". Leachate is collected and treated on-site or at a sewage treatment works, before being released to a river or the sea. Some of the leachate seeps slowly from the landfill, and mixes with water in the soils surrounding the site. This mixing is measured by taking samples from boreholes around the site boundary to ensure that levels of pollutants stay below specified limits. We were able to estimate emissions to water from landfill operations, but these estimates were only of moderate or poor quality.

Emissions from waste management operations are dependent on the material being treated (in this study, municipal solid waste or similar wastes) and the controls on emissions used at an individual facility. This means that there is a limit to which emissions from individual facilities can be evaluated in a non-site specific study such as this, because of the variations between different facilities. However, this study can give a reliable picture of national emissions, and emissions from an average or typical facility.

The timing of emissions from landfill is different to the other types of facility considered. While the emissions from other facilities happen at the same time as the waste is processed, those from landfill occur at a lower rate, but over a longer period.

The figures below set out some of the estimated emissions to air from different waste management operations. The bars on the graphs show the margin of uncertainty in the estimated emissions.

Emissions of carbon dioxide to the air

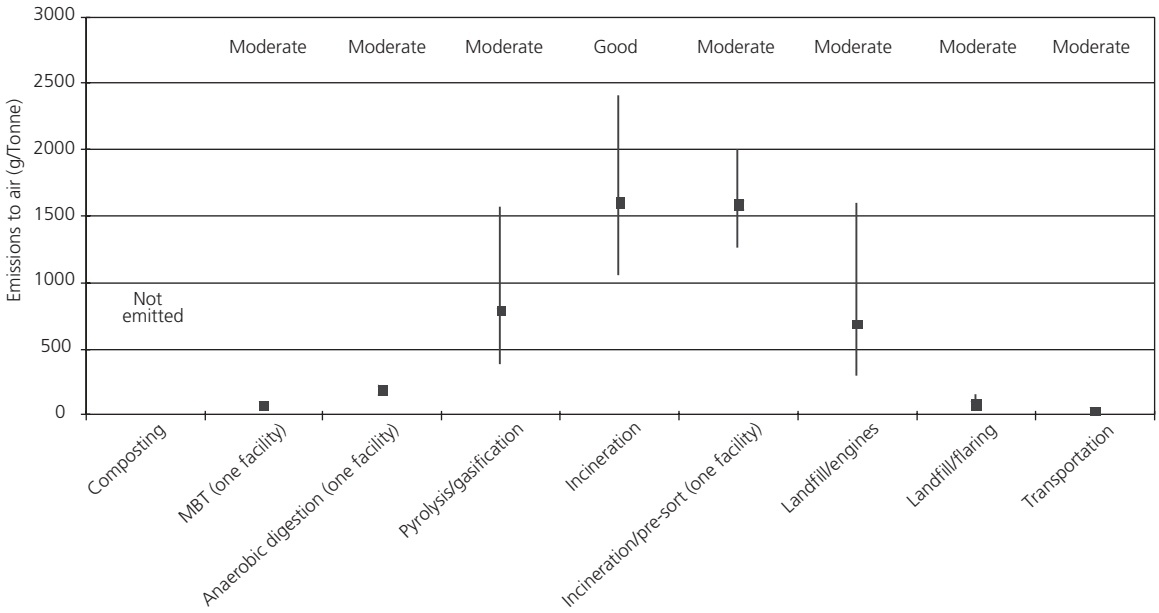


Carbon dioxide is one of the main contributors to global warming. It is emitted when municipal solid waste decomposes or is burnt. Landfill also gives rise to emissions of methane, which is a much more potent greenhouse gas than carbon dioxide. This means that landfill is the waste management option with the greatest global warming impact, even though an increasing proportion of landfill gas is burnt, which converts the methane to carbon dioxide.

The data suggest that combustion of landfill gas in an engine could give rise to higher emissions of carbon dioxide than burning landfill gas in a flare. In fact, a similar emission of carbon dioxide would be expected, and the differences mainly arise from the uncertainty in measurements of flare emissions.

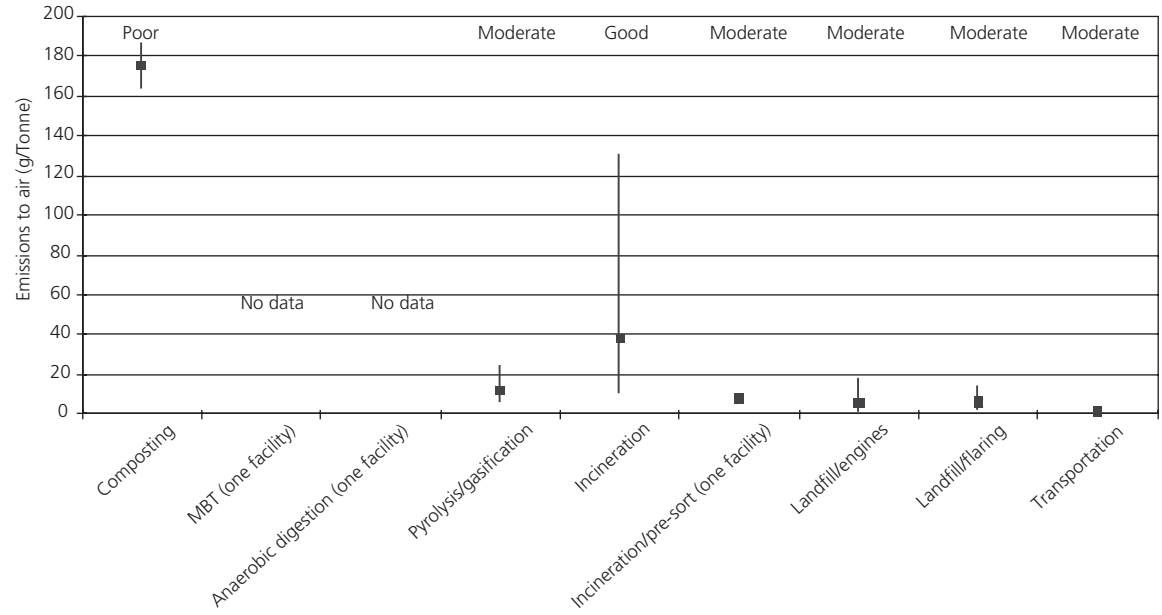
Information on emissions

Emissions of oxides of nitrogen to the air



Oxides of nitrogen (known as "NOx") are produced when municipal solid waste or gases derived from municipal solid waste are burnt. NOx produces nitrogen dioxide, which is a matter of concern regarding air quality in urban areas. Emissions of oxides of nitrogen also contribute to acid rain and excessive eutrophication – that is, increases in nutrients in rivers and lakes which stimulate excessive growth of algae, crowding out other species.

Emissions of particulate matter to the air

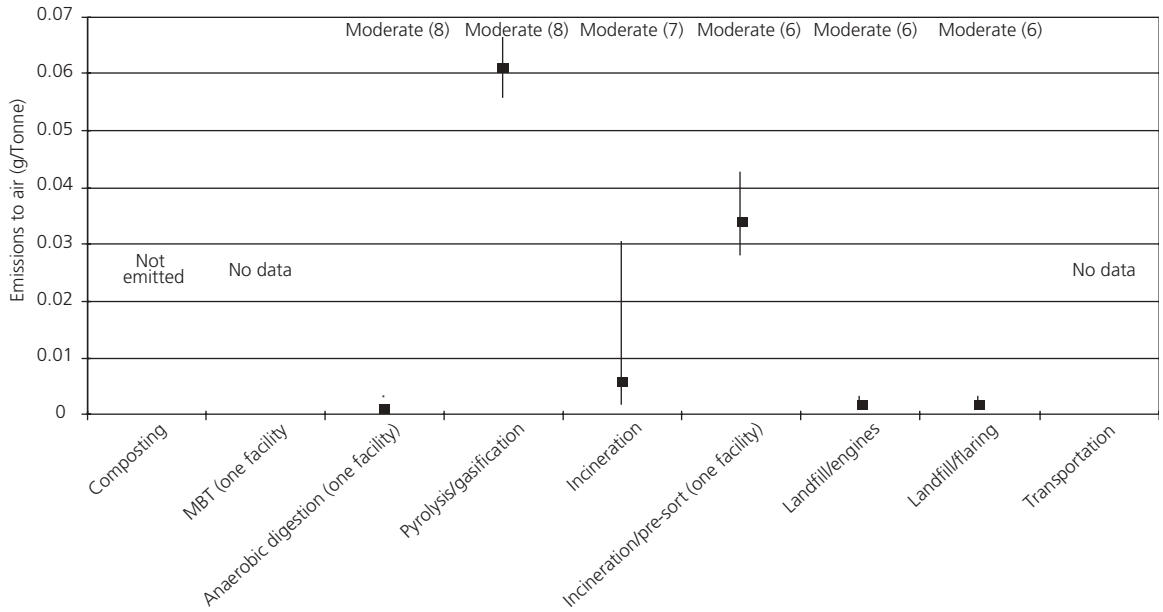


In this study, "particulate matter" means small particles of any material in the air. These may be fine dusts which can be emitted from moving waste around – for example, when turning piles of

waste during composting. Particulate matter released in this way tends to settle back to the ground soon after being released. Particulates are also emitted when waste is burnt. These emissions can be controlled using filter systems, and the particulate matter released in this way tends to be much finer and not visible to the naked eye. Fine particulate matter is a concern for urban air quality because increases in levels of particulate matter in the air are linked to general indicators of ill health, such as hospital admissions for respiratory ill health.

The wide range in estimates for incineration reflects the differences in low release concentrations in emissions from waste incinerators.

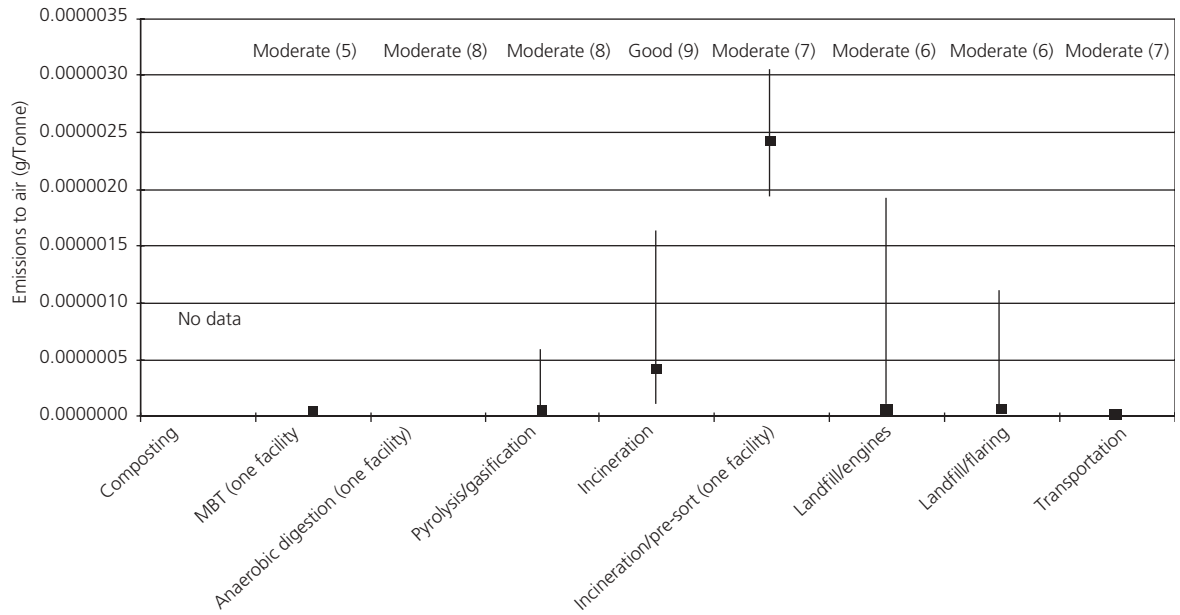
Emissions of arsenic to the air



Arsenic is one of a number of metals which can be emitted from waste management facilities, particularly when waste is burnt. If exposure is high enough, metals can have a range of effects on health – for example, arsenic can cause cancer of the skin, kidneys, lung and bladder. The figure shows a relatively high value for emissions of arsenic from pyrolysis/gasification. This value is based on measurements from a single facility, and the high value might just be due to an abnormally high measurement.

Information on emissions

Emissions of dioxins and furans to the air



There is a lot of concern expressed about exposure of the public to dioxins and furans. They are a group of chemicals which can be formed in very small quantities when organic chemicals are burnt in the presence of chlorine. Municipal solid waste was in the past a significant source of these chemicals, but following reductions in emissions from waste incineration now accounts for only 1% of emissions to the air. The developing reproductive system of male offspring seems to be particularly sensitive to exposure to dioxins before birth. Dioxins are associated with other developmental and reproductive effects, and the immune system is also potentially sensitive. UK expert committees regard dioxins as a probable human carcinogen.

A relatively high rate of emissions from an incinerator with pre-sorting was derived. This information was derived from a single process – the only operational UK plant of this type – and so is of less good quality than data for mass-burn incineration.

The main findings of this study

The main findings were as follows:

- Incineration produces the greatest emissions of oxides of nitrogen, followed by pyrolysis/gasification and landfill (information of moderate quality).
- Composting produces the highest emissions of particulates per tonne of municipal solid waste, although these data are of poor quality and would benefit from further research. Incineration is also an important source. Emissions from transport of waste are unlikely to be important.
- Sulphur dioxide emissions are similar for all processes which burn waste, or gases generated by decomposing waste (information of moderate quality). Transport of waste is unlikely to be important.

- Hydrogen chloride and hydrogen fluoride emissions are higher from processes where waste or waste gases are burnt, and incineration is the biggest source of hydrogen chloride (information of moderate quality).
- VOC emissions are likely to be greater from landfill, composting and MBT than from combustion processes. Methane emissions, which are important in global warming are highest from landfill (information of poor or moderate quality).
- Emissions of dioxins and furans per tonne of waste from incineration are higher than from other options, with other processes burning waste gases having lower emissions. Emissions from incineration in the UK have changed dramatically, with a 99.8% reduction in emissions since 1990. This was brought about following limits imposed in European Commission directives. We gained a better understanding of the factors which result in dioxin and furan emissions, and developed improved ways of stopping them being formed, and removing them from flue gases.
- Landfill is the only significant source of emissions to sewer, surface water and groundwater.
- Other than landfill, all of the processes result in other outputs. These may be useful products (e.g. compost or the digested material from an anaerobic digestion facility). Materials recycling facilities produce materials which are sent for reprocessing into useable products. This is often benefical – for example, reducing the need to use raw materials. However, it can also result in emissions – for example, if recycled materials need to be transported long distances for reprocessing. Some of the outputs can be re-used in other ways – for example, ash from waste incineration can be used in road building or to make "breeze blocks." These re-uses have the potential for releasing unwanted substances to the environment, and re-use needs to be properly controlled. Some of the outputs need to be disposed of by landfill – for example, composted material which is not of good enough quality to be used for land improvement, or air pollution control residues from waste incineration plant.

Chapter 5 describes our investigation of the possible health effects of some of these emissions by estimating exposure to the emitted substances. Chapter 7 provides information on other sources of emissions to show how important (or otherwise) these emissions are in the context of other sources of pollution in the UK.

Information on health effects

We carried out a detailed review of published literature on the health effects of waste management. The main thrust of this work was to look at studies of ill-health in populations who might be affected by waste management operations. This drew on information provided by the branch of science known as "epidemiology."

We also used information on the health effects of air pollution to investigate whether emissions to air from waste management facilities could have an effect on people's health. Much of this information also originates from epidemiological studies, but in this case, the information is not specific to waste management operations.

When looking at a particular facility it is important to take account of the local circumstances – for example, how close to the facility people live, or whether there are any pre-existing health concerns.

Epidemiology

Epidemiology is the study of the distribution (or patterns) and determinants (or causes) of disease in human populations. Epidemiologists study a wide range of health conditions, and consider the effects of exposures to causes of disease on the occurrence of disease.

Many factors may affect the patterns of disease in a population. Some of these factors are known, some are suspected, and some are unknown. It can be very difficult to disentangle them and understand the underlying causes of a disease. This means that, even when exposure to a chemical or other agent influences the rate of a disease, epidemiological studies may not be able to detect any association. It also means that, when an epidemiological study does find an association between a health effect and a measurement linked to a possible cause, it may be difficult to determine whether this is a result of cause and effect. In many cases, there are other explanations for observed associations – for example, from time to time, an apparently significant association will be observed as a result of chance, rather than because there is a cause and effect relationship.

Also, when studying the possible environmental causes of ill-health, it is important to find some way of measuring the proposed cause. In some studies, levels of a pollutant are measured, and the incidence of disease compared to the measured level of the pollutant. In other studies, distance from a possible source of pollution is used to provide an indication of exposure to emissions from the source of pollution. However, many other factors might contribute to different rates of the health effect being studied in different populations. Factors which are correlated with both the measure of exposure (for example, the distance from a possible source of pollution) and the health outcome being studied are known as 'confounding factors'. Some of the more common confounding factors are:

- The pre-existing health of the people being studied
- The wealth or poverty of the people
- The availability of health or social care services

- Lifestyle including:
  - Smoking;
  - Alcohol use;
  - Drug use (medicinal and recreational);
  - Diet;
  - Fitness;
- Occupation;
- Home environment;
- Work environment;
- Other present or historical sources of pollution;
- Movements of people into or out of a geographical area;
- Genetic factors;
- Weather and temperature.

The main health effects of concern

Landfills

Many epidemiological studies have been carried out to investigate the health effects of landfill sites. Recent research has investigated the occurrence of birth defects in infants born to families living near landfill sites in the UK. Many birth defects can be successfully treated, but even so, a birth defect is always a frightening and distressing event for the parents.

An important recent UK study looked at over eight million births in the UK between 1983 and 1999. The data were split into two groups: the first, those births where the mother lived within 2 kilometres of a landfill site and the second, those births where the mother lived further than 2 kilometres from a landfill site. The two groups were then compared to see if there was any difference between living closer to the landfill site than further away. The main problems in a study of this nature relate to possible confounding factors, which could not be completely allowed for. Also, the 2 kilometre cut-off point was a practical necessity, arising from the accuracy of the information on residential location. It might be that any effects actually take place over a different geographical area. In its favour, the study looked at a very large number of cases, and so it was able to pick up significant results at a level of a few percent, which would not be possible with a smaller scale study.

The study showed that people living within 2 km of an active or disused landfill site in the UK experienced slightly higher rates of several birth defects than people living further away. This is not the same as saying that the landfill is the cause – see our discussion of epidemiological studies above. The observed increases are shown in the following table:

Information on health effects

Outcome	Usual rate	Observed increase and rate in populations close to landfill sites	
Neural tube defect (problem with the spinal cord)	1 in 1800 births	6% (1-12%)	1 in 1700 births
Cardiovascular defect (problem with the heart or blood circulation)	1 in 750 births	No increase	1 in 750 births
Hypospadias and epispadias (mis-placed opening of the urethra)	1 in 420 births	7% (4-11%)	1 in 390 births
Abdominal wall defects	1 in 2900 births	7% (-1-12%)	1 in 2700 births
Surgical correction of gastroschisis (a type of abdominal wall defect – these will also be counted in the row above)	1 in 5300 births	18% (3-34%)	1 in 4500 births
Stillbirths	1 in 195 births	No increase	1 in 195 births
Low birth weight	1 in 16 births	6% (5.2%-6.2%)	1 in 15 births
Very low birth weight	1 in 104 births	4% (3-6%)	1 in 100 births

The figures in brackets are the 99% confidence interval – the study authors are 99% confident that the true figure lies in this range.

The study does not allow us to say whether the increases in birth defects are caused by the landfills or result from another confounding factor. However, the small scale of the increase in risk suggests that living close to landfill sites is less likely to be the cause of the increased incidence of birth defects than other influences on infant health, such as the mother's diet, smoking and alcohol intake.

The study investigated sites which opened during the period covered by the study, and found that some of the outcomes considered were at a lower rate after the site opened than before they opened. This also indicates that factors other than the landfill sites may be the cause of the observed increases. In the light of those concerns the Government's independent expert advisory Committee on the Toxicity of Chemicals in Food, Consumer Products and the Environment considered that *"it is inappropriate to draw firm conclusions on the possible health effects of landfill sites from the results of this study."*

Materials recycling facilities

A few studies have been carried out in the workplace at materials recycling facilities. These indicate that flu-like diseases, eye and skin problems, tiredness and sickness are higher in the workers than would be expected in other comparable groups. So far as we know, there are no studies of health effects in people living near MRFs. If there were any health effects, these would be expected to be similar in nature to those associated with composting facilities, in view of the similarity between the health effects which have been observed in workers at MRFs and workers at composting facilities.

Composting

A few studies have considered health effects in people near to commercial scale composting plants. There is more research into the health of people who work at composting plants. These studies show that people living near composting plants could experience an increased rate of health effects like bronchitis, coughing and eye irritation.

Subjects studied, but no health effects identified

Incinerators

Many studies have investigated how many cancer cases occur close to incinerators. These have mainly considered cancers of the stomach, colorectal, liver, lung, larynx and non-Hodgkins lymphoma. There is no consistent evidence of a link between exposure to emissions from incinerators and an increased rate of cancer. Where apparently significant effects have been observed, these are often in relation to incinerators close to other sources of potentially hazardous emissions, which makes it much harder to pin down the source of any effect. The Government's independent expert advisory Committee on the Carcinogenicity of Chemicals in Food, Consumer Products and the Environment concluded that *"any potential risk of cancer due to residency (for periods in excess of ten years) near to municipal solid waste incinerators was exceedingly low and probably not measurable by the most modern techniques"*

There is little evidence that emissions from incinerators make respiratory problems worse. In most cases the incinerator contributes only a small proportion to the local level of pollutants.

Landfills

A detailed study using similar information sources to the study of birth defects discussed above found no evidence that living close to landfill sites increases the chance of getting cancer to a level that can be measured.

Composting

A few studies have looked at emissions of volatile organic compounds (VOCs) from composting facilities, and one study looked at whether there was a cancer risk due to exposure to substances released from composting sites. The study found no additional risk of cancer in populations living close to composting facilities.

As noted above, a few studies showed that respiratory disease can increase in people living close to compost facilities, but there is no link with increased rates of asthma.

Other facilities

Studies looking at emissions from other facilities have not found evidence of health effects linked to the emissions.

Can we quantify the health effects?

Introduction

One way to find out what the health effects of waste management operations might be is to look at what is being emitted from the operation. The next step is to evaluate the *exposure* of people to these emissions – that is, the amount of these emissions that people living nearby might eat, drink, touch or breathe in. One method of doing this is to use a mathematical model to work out where the emissions go once they have left the waste management operation. Using this information, the exposure of local people can be estimated.

Another approach would in theory be to measure the exposure of people to the emissions. This kind of study is very useful in providing information on the levels of pollution that people are actually experiencing, but it is intrusive, very expensive to carry out, and is limited in the number of samples that can be taken. Also, it can be difficult to work out where the measured levels of pollution have come from – for example, road traffic and domestic cooking are also sources of some pollutants which are emitted from waste management facilities.

Either way, by comparing how much substance a person is exposed to, and looking at the possible health effects which would arise from this exposure, it is possible to estimate the health effects that would be expected to occur in people exposed to the air pollutants.

We have carried out a study using a modelling approach to look at the potential health effects of exposure to substances which are emitted to air from facilities handling municipal solid waste. A number of factors mean that this study is less than ideal:

- We are not able to consider pathways other than exposure via inhalation of airborne pollutants. This does not mean that health effects due to exposure via other pathways are necessarily less significant. However, there are controls on food and water quality which make any exposures through these routes easier to control.
- We were not able to consider all potentially harmful substances (because data on the health effects of exposures to other substances are not available).
- As noted in Chapter 3, the estimated emissions to air are subject to uncertainty.
- The forecasts provided by air dispersion models introduce some uncertainty.
- When looking at a particular facility it is important to take account of the local circumstances – for example, how close to the facility people live, or whether there are any pre-existing health concerns.

Our approach

We firstly estimated the exposure of people living near waste management facilities to emissions from the facilities. We then used factors known as dose-response factors to estimate the health effects of these exposures. A dose-response factor provides an estimate of the size of a health effect which would result from an exposure to a certain concentration or amount of a substance (the dose of the substance). These dose-response functions are subject to uncertainty due to the assumptions that must be made – for example, we assume that the health effect is directly

proportional to the dose, even at very low doses. In particular, the factors have been obtained from studies of health effects in populations exposed to high levels of pollutants in the workplace, or from studies of the effects of levels of air pollutants on public health in specific areas. Using them to estimate the health effects of emissions from individual facilities, as we have done, introduces additional uncertainty. This is because the people living close to a waste management facility may have different characteristics and different sensitivity to air pollution compared with the people in the studies from which the dose-response factors were obtained.

Many substances have a 'threshold' level, below which the body can accommodate the substance without any ill effects. The 'threshold' differs from person to person, depending on how healthy they are in the first place, and children and the elderly tend to be affected at a lower level than young and middle-aged adults. Sometimes a substance will have an effect in one person and not in someone else. We assumed that there was no threshold for the substances considered in this study – that is, that even the lowest exposures carry some risk of harm.

Results

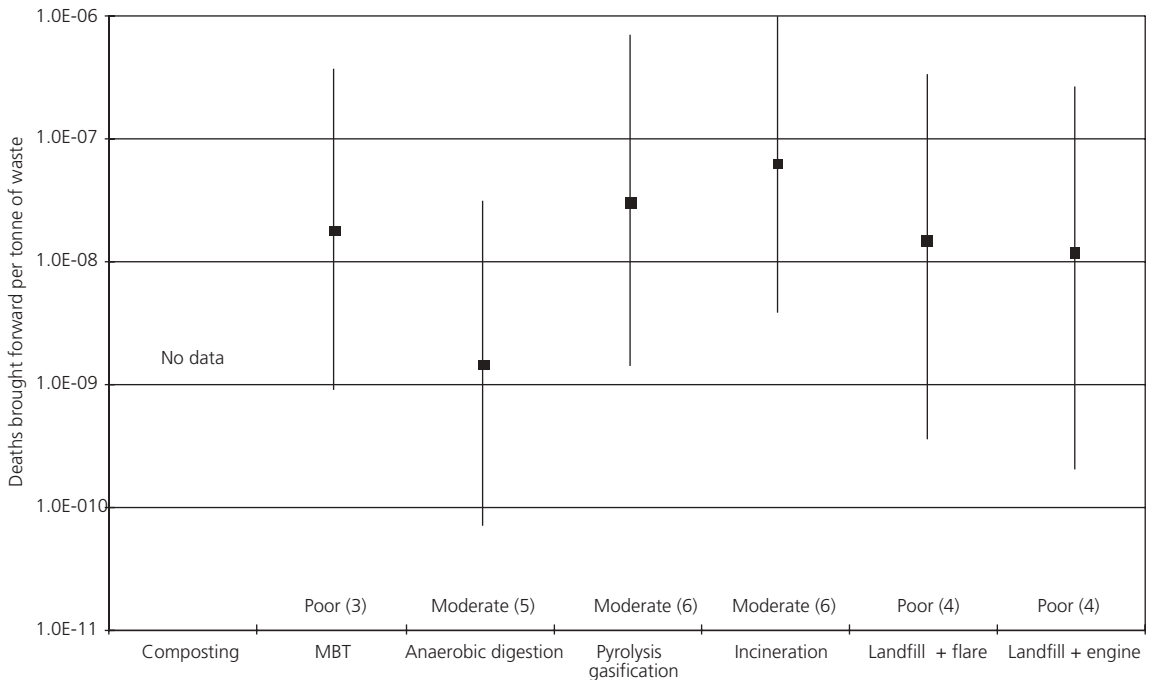
Bearing this in mind, we estimated the health effects that might arise in the general population due to emissions to air from municipal solid waste management facilities. The three figures below show the health effects which are estimated to occur due to emissions to air from waste management operation. The bars on the graphs show the margin of uncertainty in the estimated health effects, and the point in the middle of each bar shows the best estimate of the true value.

On a national scale, taking into account the amount of waste managed by each process at present, emissions to air from waste management are estimated to result in approximately five hospital admissions for respiratory disease per year, and one death brought forward due to air emission per year in the UK as a whole. Emissions to air from waste management are forecast to result in a much lower increase in the incidence of cancers – only about one additional case every five hundred years.

We were not able to estimate the potential health effects of emissions to air from composting because of a lack of information on emissions. More work on the possible health effects of composting would be useful, particularly in view of some epidemiological evidence suggesting that health effects might occur in people living very close to municipal solid waste composting facilities. Also, as noted previously, we could not do a similar calculation for emissions to water or land from facilities handling municipal solid waste. This is because public exposure to substances released via these pathways is affected to a much greater extent by site-specific factors. Individual exposure to substances released to water and land is also strongly influenced by an individual's diet and lifestyle, and by controls on the quality of water and food.

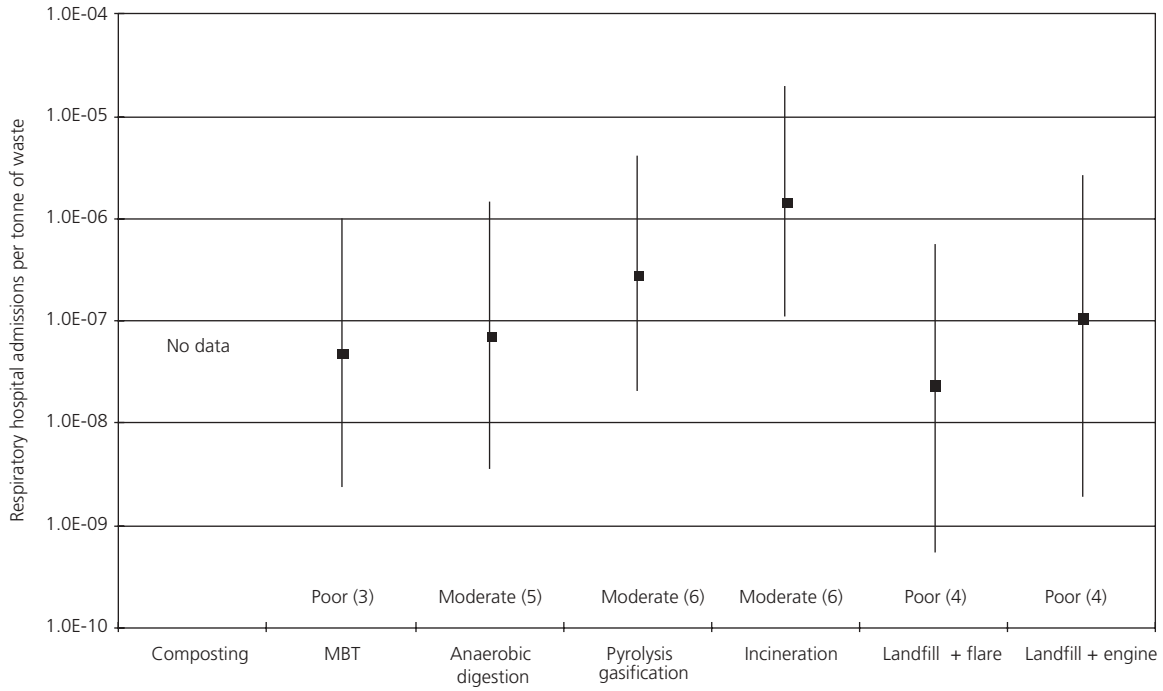
Can we quantify the health effects?

Number of deaths brought forward per tonne of waste managed



In view of the margin of uncertainty in estimated deaths brought forward, the presently available data does not allow us to say that one option for managing MSW is definitely better or worse than the other options in terms of deaths brought forward due to emissions to air.

Estimated respiratory hospital admissions per tonne of waste managed

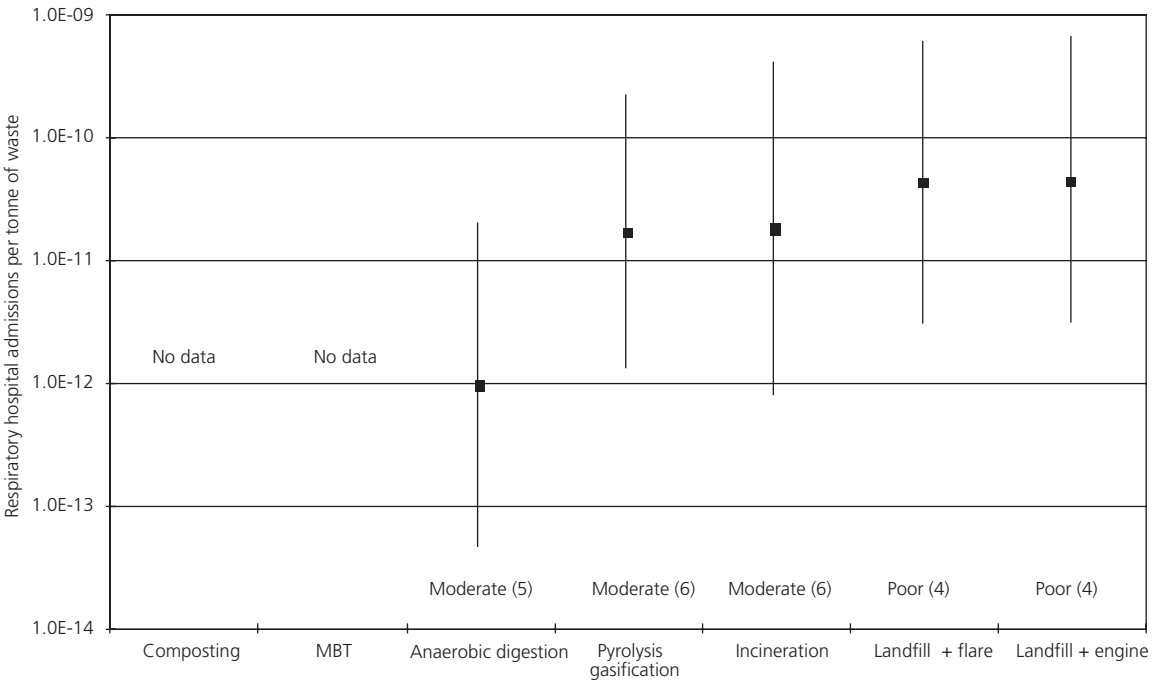


Note: "1.0E-07" means 1 _ 10^{-7}, or 0.0000001 hospital admissions per tonne of waste managed: that is, 1 hospital admission for every ten million tonnes of waste managed

In view of the margin of uncertainty in estimated respiratory hospital admissions, the presently available data does not allow us to say that one option for managing MSW is definitely better or worse than the other options in terms of hospital admissions due to emissions to air. However, there is an indication that incineration may have a greater effect on health than landfill, per tonne of waste processed. Even so, the total number of hospital admissions per year due to emissions to air from facilities managing MSW in the UK is estimated to be five per year. Although this estimate is of poor quality, the number of hospital admissions is very small compared to the total number of people admitted to hospital every year.

Can we quantify health effects?

Estimated additional cancer cases per tonne of waste managed



Note: 1.0E-10 means 1 _ 10^{-10}, or an increased risk of 0.0000000001 persons developing cancer per tonne of waste managed: that is, 1 cancer case for every ten billion tonnes of waste managed

In view of the margin of uncertainty in estimated cancer cases, the presently available data does not allow us to say that one option for managing MSW is definitely better or worse than the other options in terms of cancer cases caused by emissions to air. Although the data are of poor quality the estimated number of cancer cases is extremely small, and suggests that it would not be helpful to give further detailed attention to this area.

Information on environmental effects

What are likely to be the main environmental effects?

Waste management facilities require planning permission and prior approval from a regulator before commencing operations. Their operation is regulated with the aim of ensuring that no significant environmental harm is caused. We undertook a substantial literature search to see whether there is any evidence for significant environmental harm arising due to waste management.

When looking at particular facilities, it is important to take account of the local circumstances – for example, other sources of pollution, the presence of particularly sensitive species.

There are several possible effects of waste management operations, including: noise; odour; dust; visual intrusion; damage to plant and animals; damage to soils; pollution of water; pollution of air; emissions of global warming gases; and damage to buildings from acidic gas. Of these, the scientific evidence indicates that probably the most important on a national scale are emissions of methane from landfill sites. This is important in global warming. Odours from landfill sites can also be important, which emphasises the need for good control of odorous emissions from these sites. These are in the context of current and past practice. Changes in legislation will require greater capture of gas from landfills which will reduce these impacts.

We did not find very much evidence for other adverse environmental effects due to waste management. The table below shows the main environmental impacts of waste management facilities. The table shows that landfill and incineration are the waste management options with most potential for environmental effects. Like every waste management site, landfills and incinerators need to be designed and run properly to ensure that these impacts are minimised and controlled.

Information on environmental effects

Summary of key environmental issues

Activity	Noise	Odour	Dust	Flora/ fauna	Soils	Water quality/ flow	Air quality	Climate	Building damage
Materials recycling facility	✘	✘	✘	✘	✘	✘✘	✘✘	–	–
Composting	✘✘	✘✘✘	✘✘	✔	✘ ✔	✘✘	✘✘✘	✘	–
Mechanical biological treatment	✘✘	✘✘✘	✘✘	–	–	✘✘	✘✘	✘	✘
Anaerobic digestion	✘✘	✘✘	✘	✘ ✔	✘ ✔	✘✘	✘✘	✘	✘
Gasification/ pyrolysis	✘✘	✘✘	✘✘	–	–	–	✘✘	✘	✘
Incineration with pre-sorting	✘✘	✘✘	✘✘✘	✘✘	✘✘	✘✘	✘✘✘	✘	✘
Incineration	✘✘	✘✘	✘✘✘	✘✘✘	✘✘✘	✘✘✘	✘✘✘	✘	✘
Landfill	✘✘✘	✘✘✘	✘✘	✘✘✘ ✔	✘✘✘	✘✘✘	✘✘✘	✘✘✘✘	✘
Waste transfer stations	✘✘	✘✘✘	✘	–	–	✘✘	✘	✔	–

Category	Meaning
✔	Direct or indirect benefit
–	No effect
✘	Unlikely to be significant
✘✘	Potentially significant impact in some cases, but can be controlled
✘✘✘	Impact can normally be controlled, but an issue at sites if design, engineering or operation falls below best practice
✘✘✘✘	An issue at all sites

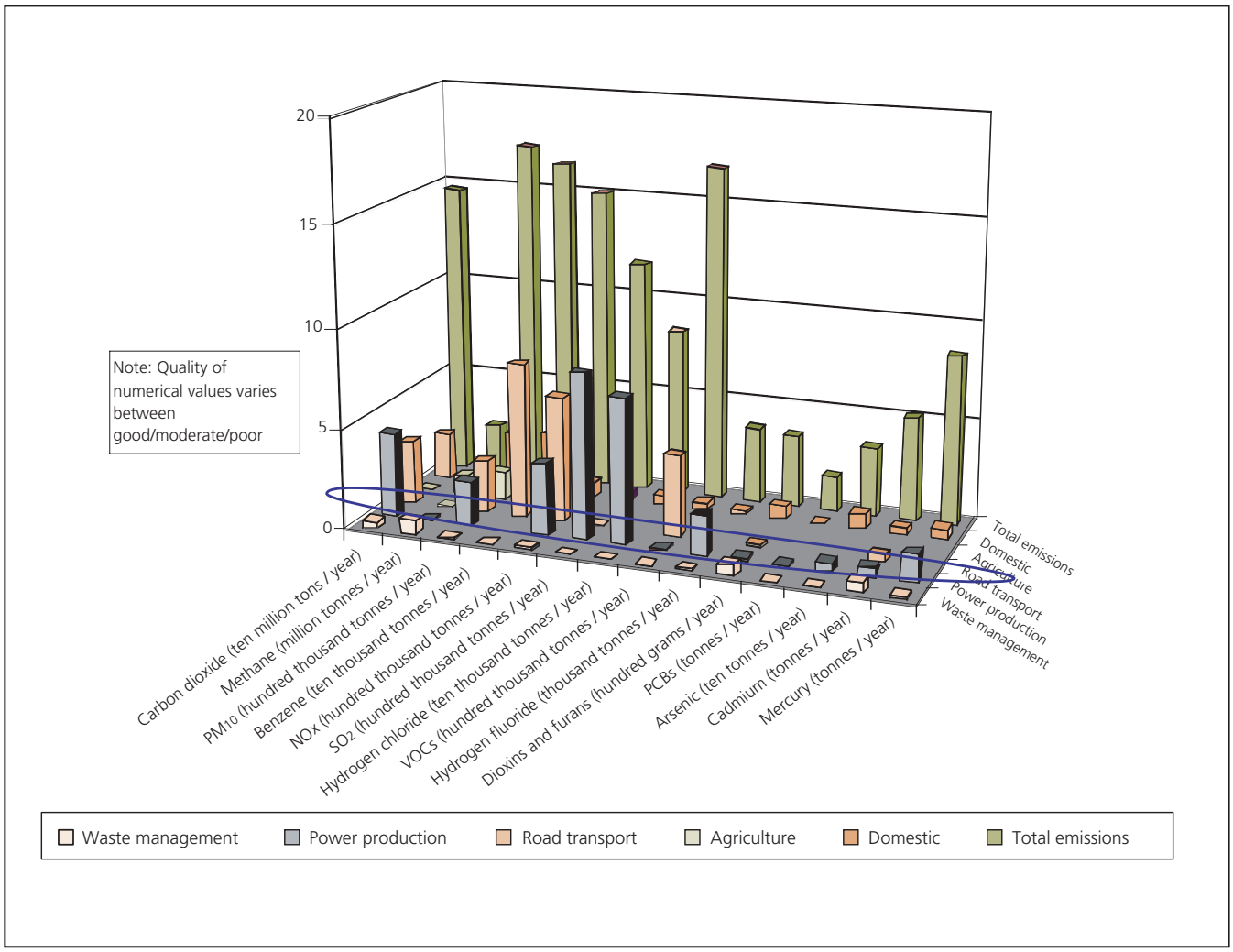
The most significant effects reported in the scientific literature were in respect of global warming impacts. We found that avoiding the landfill of municipal solid waste gave a benefit in avoiding emissions of methane which would otherwise have a significant effect on global warming.

Putting things in context

Effects of waste management in the context of other activities in the UK

Managing municipal solid waste accounts for a small proportion of most emissions in the UK: less than 2.5% (one fortieth) of almost all emissions which we were able to quantify (this information is mostly of good quality). The exceptions to this are emissions to air of methane (which accounted for nearly 30% of the UK total) and cadmium (10% of the national total). Almost all of the cadmium emitted to air from facilities dealing with MSW comes from landfill sites.

This is illustrated in the figure below, which compares emissions to air from management of municipal solid waste and similar wastes, and other sources of pollution. The front columns (circled) represent emissions from waste management. Apart from the emissions of methane, these show that waste management makes a very small contribution to emissions of air pollutants compared with other sources of pollution and the national total emissions.



Putting things in context

Where possible, we have estimated emissions from landfill of municipal solid waste to surface water and groundwater (see below). While the lack of data means that the numbers themselves are of poor quality, they indicate that emissions from waste management are a very small proportion of total UK emissions.

Substance	Landfill releases to groundwater/ surface waters	Landfill releases to sewer		All UK releases to water
		To STW	From STW to receiving waters	
	Tonnes per year	Tonnes per year	Tonnes per year	Tonnes per year
Total nitrogen	232	1062		400,000
Organo-tin compounds	0.00013	0.00058	0.0000023	0.45
Phosphates	1.9	8.7		33000
Pentachlorophenol	<0.000026	<0.00025	<0.000035	3.4
Copper	0.0035	0.027	0.0091	590
Lead	<0.032	<0.15	<0.071	480
Zinc	0.026	0.31	0.12	2400

A similar picture emerges when considering the health effects of emissions to air from facilities handling municipal solid waste – other influences on health appear to be much more important, even for people living very close to municipal solid waste management facilities.

Health impact	Number per year in the UK due to			
	Handling municipal solid waste	Skin cancer (main UK causes are sunlight and sunbeds)	Lung cancer due to passive smoking	Health impacts due to air pollution
Deaths brought forward	0.55 (about one nationally per year)			11,600 (about one per small town per year)
Hospital admissions	4.9 (about five nationally per year)			14,000 (about one per small town per year)
Cancers	0.0014 (about one nationally every seven hundred years)	6,000 (about one per small town per year)	several hundred (about one per large town per year)	
Data Quality	Poor	Moderate	Poor	Poor

We have also compared the hazards from municipal solid waste management with other health hazards like accidents in the home or workplace, accidents caused by fireworks, traffic accidents or environmental factors such as excessive cold. Emissions from municipal solid waste are much less significant than these other hazards. For example, fireworks resulted in over 1000 hospital admissions in 2002. Traffic accidents result in over 3,000 deaths and over 300,000 hospital admissions every year. This compares with about one death brought forward and five hospital admissions every year due to emissions to air from managing municipal solid waste.

Conclusions

We have looked at the available information on the health and environmental effects of waste management. While the information is incomplete and not ideal, the weight of evidence from the studies so far is that present-day practice for managing municipal solid waste has at most a minor effect on human health and the environment. This should be viewed in the light of the benefits of collection and disposal of the waste that we all generate. If waste were not collected, treated and disposed, it would become a source of disease, odours, litters and pests.

We recommend that efforts continue to be made to reduce the amount of municipal solid waste generated by and for us all. The government, regulators and the waste management industry should continue to be vigilant and improve their own understanding of the effects of municipal solid waste management, so that we can better regulate and control this essential industry. This will need to be communicated to the public so that we can all develop a proper perspective on the health and environmental effects of MSW.

Specifically, we recommend that a number of further studies would be helpful in improving our understanding of the health and environmental effects of waste management. The most important areas to investigate are:

- A field study of population exposure to substances emitted from landfill sites;
- A study to improve our understanding of releases of micro-organisms from all kinds of waste management facilities;
- A study to improve our understanding of releases of particulates, micro-organisms, VOCs and methane from composting of municipal solid waste;
- A study to improve our understanding of releases from MBT and anaerobic digestion of municipal solid waste.

Other areas where further work should be considered include looking at whether an increase in composting of MSW could have an effect on our health; looking at emissions under non-standard operating conditions; investigating the health and environment effects of recycling processes; and ongoing study of new ways of dealing with MSW.