Review of research into health effects of Energy from Waste facilities

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Contact:

Dr Mark Broomfield
AEA Technology plc
2 Kelvin Close, Birchwood, Warrington,
WA3 7PB

t: 0870 190 6389

f: 0870 190 6933

e: mark.broomfield@aeat.co.uk

AEA is a business name of AEA Technology plc

AEA is certificated to ISO9001 and ISO14001

Author:

Mark Broomfield

Approved By:

Andrew Lelland

Date:

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AEA reference:

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Executive summary

AEA Technology was commissioned by the Environmental Services Association to carry out a review of published research on the health effects of Energy from Waste (EfW) facilities. The scope of this study was to carry out a review of the health and environmental issues potentially associated with waste incineration/EfW facilities, together with brief consideration of other waste thermal treatment techniques, as currently practised in the UK, focusing on MSW and similar wastes. Recovery of energy from waste by incineration is a key component of the Government's waste hierarchy.

Waste incinerators have been in existence for over 100 years. Incineration was a largely unregulated activity until the introduction of the Municipal Waste Incineration directives of 1989 (89/429/EEC and 89/369/EEC). Emissions limits and controls were further tightened following the introduction of the Waste Incineration Directive (2000/76/EC). To comply with the requirements of the Waste Incineration Directive, waste incinerators are now required to reduce residual emissions of these substances to much lower levels than those which took place before the implementation of the Directive. The provisions of the Waste Incineration Directive are reproduced in the Industrial Emissions Directive (2010/75/EU).

The key issues which give rise to plausible concerns resulting in research with regard to EfW facilities are as follows:

- Process emissions
    - Nanoparticles/ultrafine particles
    - Dioxins and furans
    - Emissions during abnormal operating conditions
- Health outcomes
    - Infant mortality
    - Infant development problems
    - Carcinogens and cancer risk
    - Respiratory disease

EfW facilities make a small contribution to environmental levels of ultrafine particles, analogous to the findings in relation to larger particles. Modern MSW incineration facilities emit much lower levels of dioxins and furans than those from incineration facilities in the past – a reduction of over 99% since 1990. This means that MSW incineration is now no longer a significant source of emissions to air of dioxins and furans, contributing only 2.5% of UK emissions. More significant sources include accidental fires and open burning of waste, agricultural straw burning, the iron and steel manufacturing industry, and crematoria. Similar conclusions apply to other comparable waste thermal treatment facilities.

Abnormal operating conditions can affect emissions. These situations need to be taken into account during the planning and permitting process. Studies of the health and environmental effects of operational EfW facilities take account of the full range of operating conditions, both under normal conditions, and under any abnormal operating conditions that may have occurred.

While there is always some uncertainty in the findings of health studies, it is concluded that well-designed EfW facilities as currently operated in the UK are most unlikely to have any significant or detectable effects on cancer incidence, the incidence of adverse birth outcomes (including infant mortality), or the incidence of respiratory disease.

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1 Introduction

AEA Technology was commissioned by the Environmental Services Association to carry out a review of published research on the health effects of Energy from Waste (EfW) facilities. The scope of this study was to carry out a review of the health and environmental issues potentially associated with waste incineration/EfW facilities, together with any other waste thermal treatment techniques, as currently practised in the UK, focusing on MSW and similar wastes.

The study takes account of the findings of reviews published by bodies such as the Health Protection Agency and Scottish Environmental Protection Agency/NHS Scotland. A search for more recent scientific literature was also carried out.

The report is structured as follows:

Chapter 2: Review of relevant health and environmental issues

Chapter 3: Conclusions

This study does not address the issue of whether energy from waste is an appropriate form of waste treatment at a strategic or a local level.

In this report, the term "Energy from Waste" is used interchangeably with "Incineration." Generally, "incineration" is used to refer to facilities operating prior to the implementation of the Waste Incineration Directive. The implementation of this directive required the recovery of energy as heat and/or electricity. Consequently, facilities operating after the implementation of the Waste Incineration Directive are generally referred to as "Energy from Waste" facilities. Where reference is made to other forms of energy recovery from waste, this is clearly highlighted in the text.

AEA Technology is a global sustainability consultancy with world-leading energy, climate change and environmental expertise. AEA provides a complete suite of policy, advisory and implementation services on air and water quality, with expertise in environmental data systems, local and mesoscale modelling, assessment and forecasting, air quality and emissions monitoring, and regulatory policy.

The main report author, Dr Mark Broomfield, is an air quality, odour and health impacts specialist with a BA in chemistry from the University of Cambridge, and a PhD in atmospheric chemistry. He has worked in these areas since 1992, both within the consultancy sector and as an industry specialist at ICI. Mark was the lead author for the Defra study "*Review of Environmental and Health Effects of Waste Management*" in 2004. He has carried out air quality and health studies and reviews in relation to EfW and biomass facilities for the waste industry, project developers, local authorities and community groups. He works with local authorities and other stakeholders to achieve consensus on health and environmental issues relating to waste management. Mark contributes to seminars and conferences on air quality, health and waste-related topics – for example, as a contributor to Cranfield University's Risk Assessment masterclass. He is a Visiting Research Fellow at the University of the West of England.

2 Review of relevant health and environmental issues

2.1 Historical context

Waste incinerators have been in existence since the late 19th century; however, by 1945, waste incineration in the UK was at a very low level. Incineration re-emerged in the 1960s, but was a largely unregulated activity until the introduction of the Municipal Waste Incineration directives of 1989 (89/429/EEC and 89/369/EEC). These directives laid down operational requirements and some emissions limits on waste incineration facilities. Waste incinerators were regulated under Integrated Pollution Control following the introduction of this regime under the Environmental Protection Act 1990. Emissions limits and controls were further tightened following the introduction of the Waste Incineration Directive (2000/76/EC), and the implementation of Integrated Pollution Prevention and Control (IPPC).

This historical perspective highlights the change that has taken place in waste incineration facilities over the period since the development of a previous generation of facilities in the 1960s. The changes in design and operation of waste incineration facilities over this period must be taken into account when interpreting the findings of health studies, and must also be considered in developing an understanding of public views and perceptions of waste incineration.

To identify the relevant health and environmental issues associated with waste incineration, the starting point is to consider the nature of the process. The term “waste incineration” describes the process by which the combustible components of waste materials (such as organic materials and plastics) are burnt under controlled conditions. Carbon and hydrogen in the waste are converted to carbon dioxide and water respectively, and consequently the main components of emissions from a waste to energy facility are carbon dioxide and water, together with nitrogen and oxygen from the air. The residual component of the combustion process and non-combustible components of the waste, such as metals and minerals, are removed from the incinerator as ash.

Recovery of energy from waste by incineration is a key component of the Government’s Waste Hierarchy (Defra, 2011). The highest priority is given to preventing waste in the first place. When waste is created, the Waste Hierarchy gives priority to preparing it for re-use, then recycling, then other recovery such as energy recovery, with disposal as the lowest priority.

A number of other substances are formed during the combustion process, of which the main constituents are acid gases – oxides of nitrogen (made up of nitric oxide and nitrogen dioxide), sulphur dioxide, hydrogen chloride and hydrogen fluoride. Small quantities of particulate matter, carbon monoxide and volatile organic compounds are present in the flue gases. Much lower quantities of metals are also present in the flue gases, together with smaller quantities still of partial combustion products such as dioxins and furans, polychlorinated biphenyls and polycyclic aromatic hydrocarbons. Waste incinerators result in the production of ash from the combustion process and from the air pollution control systems.

In the past, emissions to air from waste incinerators were at levels which were of concern with regard to potential health and environmental effects. To comply with the requirements of the Waste Incineration Directive and the permitting regimes, waste incinerators are now required to reduce residual emissions of these substances to much lower levels than those which took place before the implementation of the Directive. This requires a combination of methods including mixing of waste materials, control of combustion conditions, gas scrubbing, carbon injection, and abatement of particulates using bag filter technology. In practice, most waste to energy facilities now give rise to emissions to air at levels which are well below the Waste Incineration Directive limits. Compliance with these limits is enforced via Environmental Permit conditions.

2.2 Key issues

The key issues which give rise to plausible concern with regard to EfW facilities are as follows:

- Process emissions
  - Nanoparticles/ultrafine particles
  - Dioxins and furans
  - Emissions during abnormal operating conditions
- Health outcomes
  - Infant mortality
  - Other adverse birth outcomes
  - Carcinogens and cancer risk
  - Respiratory disease
- Other waste thermal treatment techniques

These issues are addressed in the following sections.

2.3 Process emissions

2.3.1 Nanoparticles/ultrafine particles

Level of particulate emissions: As described above, emissions of particulate matter from modern EfW facilities are limited under the provisions of the Waste Incineration Directive. The emission limit applicable to particulate matter emissions is 10 milligrams per normalised cubic metre (mg/Nm^3). Most facilities are equipped with bag filters, and emissions are typically 1-2 mg/Nm^3. This typically results in a slight contribution from a waste incineration facility to environmental levels of particulate matter, and this contribution would not be significant in terms of potential environmental or health effects. In a national context, the contribution from EfW facilities to levels of particulate matter is even less than in the local context, with MSW incineration giving rise to 0.042% of UK emissions of fine particles (referred to as “$PM_{2.5}$”) in 2009 (NAEI, 2011). More significant sources include road traffic (29% of UK total), residential combustion (14%) and electricity generation (5.5%)

Relevance of nanoparticles: The above information addresses the larger fractions of airborne particulate matter. It may be the much smaller particles ("ultrafine" or "nano" particles – that is, particles with a diameter of 0.1 microns or less) which are of concern with regard to their effects on health. It is also plausible that the risks to health associated with particulate matter are more closely linked to the number of particles, rather than the mass of particles.

Size distribution of particles: As with other sources of airborne nanoparticles, there is limited data on emissions of nanoparticles from EfW facilities. Recently published research describes measurements of particulate matter emitted from a waste to energy incinerator in Piacenza, Italy (Buonanno et al. 2009). The study found that no particles with aerodynamic diameters greater than 2.5 µm were present in emissions to air. 65% of the measured $PM_{2.5}$ mass was from sub-micrometre particles (PM_1) and the contribution of $PM_{0.1}$ to the mass of particulates was negligible. Most of the mass was from particles that were between 0.1 and 1 microns in aerodynamic diameter (see Figure 1(a)). The numbers of particles were distributed approximately equally between particles greater than and less than 0.1 micron (see Figure 1(b)).

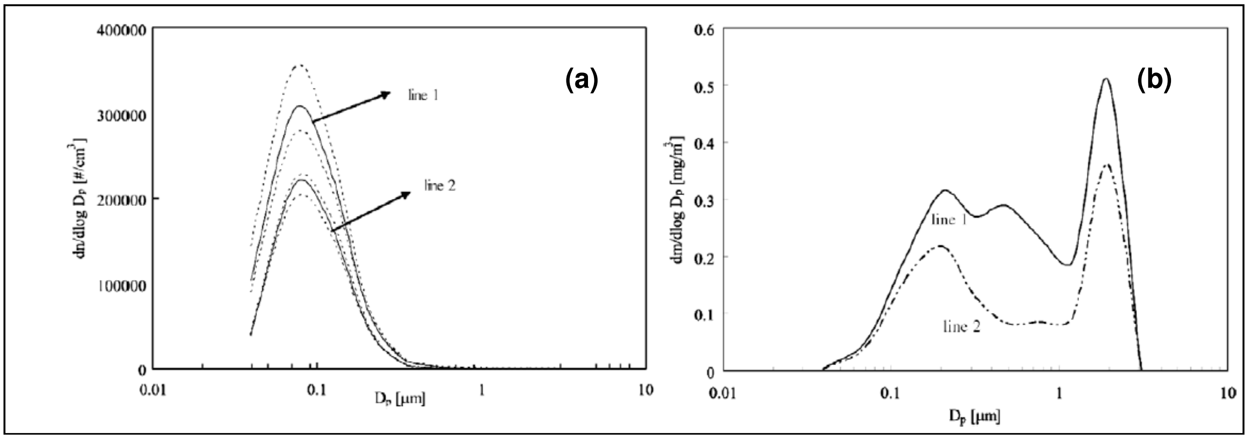

Figure 1: Particle mass and particle number size distribution (from Buonanno et al., 2009)

Contribution of EFW particulate emissions to background levels: These findings indicate that EfW facilities would be expected to make a small contribution to environmental levels of ultrafine particles, analogous to the findings in relation to larger particles. This was found to be the case in a subsequent environmental monitoring survey of particle number and size distribution (Buonanno et al., 2010). Levels of particulate matter were found to be low in the Italian context. An analysis of the elemental composition of particulates indicated that sources other than the EfW facility accounted for all the elements present, and the contribution from the EfW facility was not detectable.

A further study (Buonanno et al., 2011) found that the abatement systems used at the facility under consideration were effective in removing approximately 99.99% of particulate matter, with efficiency reducing to some extent for particles with smaller diameter. Higher boiling point elements such as chromium were found to be more prevalent in higher particle sizes, while lower boiling point elements such as arsenic and cadmium were more prevalent in smaller particle sizes.

In a separate study of fine and ultrafine particles on the surface of foodstuffs in Italy, the authors concluded that "*little evidence is found for particles whose origin could be attributed to industrial combustion processes, such as waste incineration*" (Giordano et al., 2011). Similarly, Morishita et al. (2011a and 2011b) found that waste incineration facilities made a minimal contribution to $PM_{2.5}$ levels in urban environments in the United States. These findings are consistent with a minimal and non-detectable contribution of waste incineration to environmental levels of ultrafine particulate matter. More significant sources included road traffic, industrial sources and secondary particulates.

A study carried out in the city of Boras, Sweden claimed that waste incineration had been identified as a major source of $PM_{2.5}$ in the city (Aboh et al., 2007). In fact, the identification of incineration was no more than a tentative indication based on an assumed and potentially inaccurate emissions profile. As clarified in a subsequent paper (Laursen et al., 2009), the study technique could not uniquely identify the incinerator as a source of $PM_{2.5}$, and conclusions were limited to a finding that identification of some point sources might be possible.

2.3.2 Dioxins and furans

Emissions to air of dioxins and furans from modern MSW incineration facilities are substantially less than those emitted from incineration facilities in the past. This has stemmed from the introduction of a demanding emission standard under the Waste Incineration Directive which has led to substantial reductions in emissions of dioxins and furans through improved design and operation of emission control techniques.

These changes mean that MSW incineration is now no longer a significant source of emissions to air of dioxins and furans. This is illustrated in Figure 2.

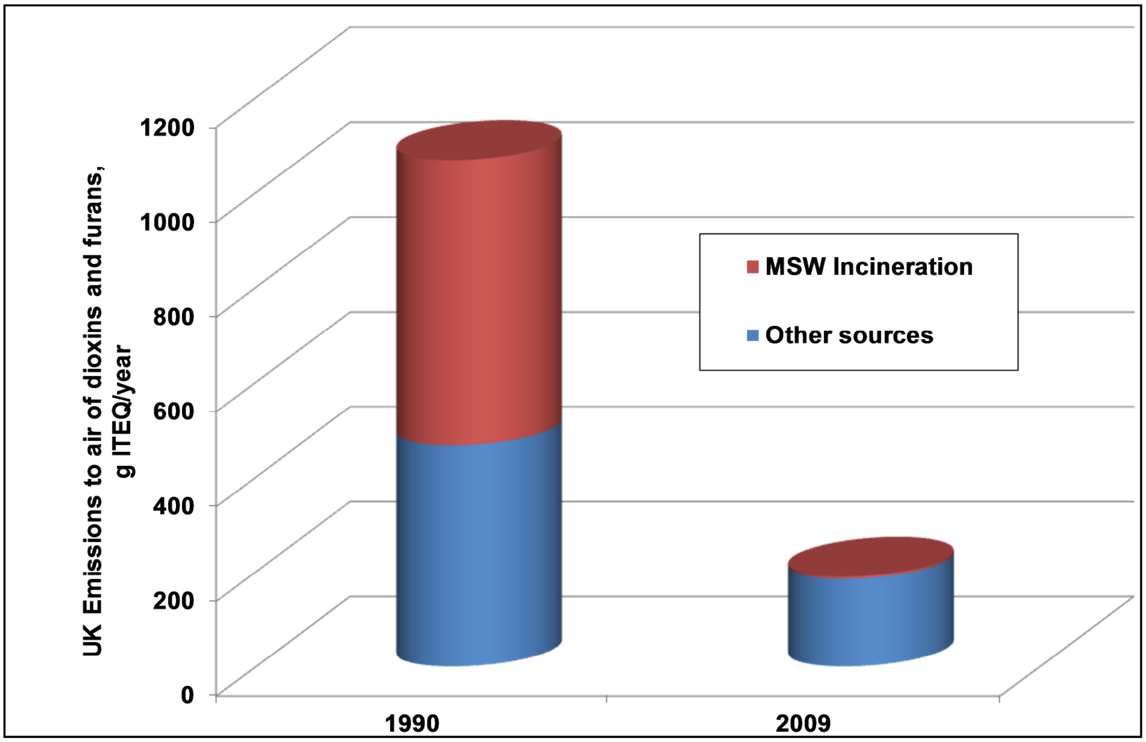

Figure 2: Emissions to air of dioxins and furans from the UK (NAEI, 2011)

In a national context, EfW facilities now account for approximately 2.5% of UK emissions to air of dioxins and furans, and have reduced by over 99% since 1990. More important sources in 2009 included accidental fires and open burning of waste, agricultural straw burning, the iron and steel manufacturing industry, and crematoria.

In a local context, it remains important to ensure that emissions to air of dioxins and furans from EfW facilities do not have significant environmental and health effects. This is normally carried out using exposure assessment techniques. Because of the minimal emissions of dioxins and furans from current EfW facilities, it can normally be demonstrated that any individual facility will have no significant adverse effects on health or the local environment.

De Felip et al. (2008) studied levels of dioxins and furans in blood serum of people living close to two incinerators in Italy. This study found no detectable difference between dioxin and furan levels in individuals living close to the incinerators compared to those in an “unexposed” reference group living more than 5 km from an incinerator. Similarly, no significant difference was observed in levels of dioxins and furans in animal feed and milk samples in samples taken close to incinerators compared to unexposed reference samples (Ingelido et al., 2008). Reis et al. (2007a and 2007b) found no detectable effect of emissions from an EfW facility in Portugal on levels of dioxins and furans in blood serum or human breast milk. These findings are consistent with a slight and insignificant contribution to exposure to dioxins and furans from the incinerator facilities.

Consistent with a minor contribution from EfW facilities to emissions of dioxins and furans, risk assessment studies carried out by Cocarta et al. (2009) and Lonati et al. (2007) found that emissions of dioxins and furans from EfW facilities in Italy did not pose any significant health risk. Cocarta et al. found that other waste treatment technologies such as Mechanical

Biological Treatment (MBT) were potentially of greater concern and should also be accompanied by a health risk assessment.

2.3.3 Abnormal operating conditions

As with any industrial facility, EfW facilities can be subject to occasional operational difficulties resulting in abnormal operating conditions and potentially increased emissions. Shut-down and start-up processes can also potentially result in higher emissions than normal operations. A measurement study carried out for the Environment Agency (2008) found emissions of dioxins and furans were increased during shutdown and start-up phases, where the waste was not fully established on the grate. The measured increases in emission concentration and emission rate were not as high as reported elsewhere, and the mass of dioxin emitted during shutdown and start-up for a four day planned outage was similar to the emission which would have occurred during normal operation in the same period.

The effective enforcement of Environmental Permit conditions provides a safeguard with regard to abnormal operating conditions, as a breach of permitted emission levels would result in the shutdown of the facility. Nevertheless, these conditions need to be taken into account in studies using forecasting or modelling techniques to predict the health risks associated with EfW facilities. Consideration of abnormal operating conditions is a requirement of the planning and permitting process in the UK.

Studies of the health and environmental effects of operational EfW facilities take account of the full range of operating conditions. These studies provide information on the net effect of operational facilities, both under normal conditions, and under any abnormal operating conditions that may have affected the health or environmental indicators under consideration. Hence, for example, the studies of environmental levels of fine particulate matter and dioxins and furans referred to in Sections 2.3.1 and 2.3.2 above include the effects of any abnormal operating conditions at the facilities studied. Similarly, the studies of health outcomes discussed in Section 2.4 below also include the effects of any abnormal operating conditions.

EfW facilities are fitted with process and emissions monitoring equipment. Continuous monitoring is carried out of a wide range of emissions, including substances of concern with regard to potential effects on health such as oxides of nitrogen and particulate matter. Other substances such as dioxins and furans and metals cannot be measured continuously. Emissions to air of these substances are controlled by ensuring good combustion conditions in the process together with well designed and operated air pollution control. The presence of low levels of substances such as carbon monoxide and volatile organic compounds in emissions to air is indicative of good combustion conditions. The levels of dioxins and furans and metals in emissions are measured periodically (typically two or four times per year) to ensure that the expected performance is being maintained.

2.3.4 Other substances

Recent studies have measured airborne volatile organic compounds and bioaerosols (Vilavert et al., 2011) and metals in blood serum (Reis et al., 2007c) and soils (Wang et al., 2011) in the vicinity of EfW facilities. These studies found no significant difference in levels of these substances close to the EfW facilities compared to control groups. These findings are consistent with a slight and insignificant contribution to exposure to these substances from the EfW facilities under consideration.

2.4 Health outcomes

2.4.1 Overview

The risks to health posed by EfW facilities have been studied for many years. These studies have recently been reviewed by bodies including the Committee on Carcinogenicity, the Health Protection Agency and Health Protection Scotland/SEPA.

The Committee on Carcinogenicity (2000) considered in particular a detailed study carried out by Elliott et al. (1996) and concluded that:

> "*any potential cancer risk due to residency (for periods in excess of 10 years) near to municipal solid waste incinerators was exceedingly low and probably not measureable by the most modern techniques.*"

In a subsequent study (Elliott, 2000), the authors reviewed the classification of liver cancers in the 1996 study. This re-evaluation found that other factors appeared to be the most likely explanation for the observed increase in the incidence of liver cancers.

The Committee on Carcinogenicity (2009) subsequently reviewed seven further studies on the incidence of cancer in populations living near to EfW facilities, and concluded:

> "*although these studies indicate some evidence of a positive association between two of the less common cancers … and residence near to incinerators in the past, the results cannot be extrapolated to current incinerators which emit lower amounts of pollutants.*"

The Health Protection Agency (2010) drew on the COC reviews and other information, and concluded:

> "*Modern, well managed incinerators make only a small contribution to local concentrations of air pollutants. It is possible that such small additions could have an impact on health but such effects, if they exist, are likely to be very small and not detectable.*"

Health Protection Scotland/SEPA (2009) carried out a detailed literature review, and concluded:

> "*Based on the limitations of available research literature, attempting to provide an overall conclusion on the health effects of incineration in total is particularly difficult.*
>
> *For waste incineration as a whole topic, the body of evidence for an association with (non-occupational) adverse health effects is both inconsistent and inconclusive. However, more recent work suggests, more strongly, that there may have been an association between emissions (particularly dioxins) in the past from industrial, clinical and municipal waste incinerators and some forms of cancer, before more stringent regulatory requirements were implemented.*
>
> *For individual incineration waste streams (clinical, hazardous, industrial and municipal), the evidence for an association with (non-occupational) adverse health effects is inconclusive.*
>
> *The magnitude of any past health effects on residential populations living near incinerators that did occur is likely to have been small.*
>
> *The majority of research work in this field is of historical relevance but tells us little about the current risk of (non-occupational) adverse effects potentially associated with incineration plants in operation now.*
>
> *Levels of airborne emissions from individual incinerators should be lower now than in the past, due to stricter legislative controls and improved technology. Hence, any risk to the health of a local population living near an incinerator, associated with its emissions, should also now be lower.*"

The HPS/SEPA review highlighted concerns that the quantity of waste incinerated could increase in the future, which could have the potential to result in an increased health burden. In view of these concerns and the limitations of health effect studies described above, HPS/SEPA concluded that a precautionary approach should continue to be taken by the regulatory and planning authorities. HPS/SEPA found that current planning/permitting measures were adequate for the control of health effects, and there was no need to introduce further controls.

In overall terms, these reviews indicate that there may have been effects on health due to the operation of waste incineration plant in the past. In view of the substantial reductions in emissions from EfW facilities in the past two decades, any effects associated with facilities operated to current standards are likely to be very small and not detectable. However, the health issues that may have occurred in the past indicate the importance of controls on emissions, ensuring that the limits set by the Waste Incineration Directive are met, and thereby ensuring that the potential health issues do not arise

2.4.2 Carcinogens and cancer risk

Nature of the risk: In common with many other activities, EfW facilities are responsible for emissions of substances which are known or suspected carcinogens. The substances of concern include dioxins and furans, polycyclic aromatic hydrocarbons and some metals. These substances were emitted at much higher levels from older plant operating prior to the implementation of the Waste Incineration Directive. Exposure to these substances results in increased risk of cancers for the exposed population.

Difficulty of characterising risk: A wide range of studies has been carried out to investigate the significance of these risks. Studies of these health risks are subject to difficulties for reasons which include the following:

- There are problems in relation to the long latency of some cancers – that is, there may be a period of years or decades between exposure and the occurrence of cancer. This may make detection and attribution of any association to a hazardous environmental exposure particularly difficult.
- There are particular problems when rare health outcomes are studied, due to the difficulty of interpreting variation in small numbers of cases and the risks of false identification of clusters due to random variation.
- It is difficult to establish the exposure of groups potentially affected by emissions from EfW facilities. Distance from a facility is often used as a surrogate for exposure to emissions. In practice, exposure may have been variable or intermittent, and affected by factors such as weather patterns and availability of locally sourced foods.
- There are likely to be other sources of the substances of concern which could affect the population under consideration, as well as other factors such as diet and lifestyle which need to be taken into account.

These factors make it harder to identify any effects which may be associated with emissions of carcinogenic substances to the environment.

Historic risk from older facilities: The reviews summarised in Section 2.4.1 conclude that there may have been a detectable increase in cancer risk associated with exposure to emissions from waste incineration facilities in the past. A similar view was reached by the Associazione Italiana di Epidemiologia (2008), which concluded that:

> "*there is convincing evidence of an association between exposure to emissions from old generation incinerators (dioxins, in particular) and increased frequency of malignancies at various sites. Although it is possible that these emissions may have produced other effects (carcinogenic or not), the available data are not sufficient to corroborate the hypothesis.*"

Risk from current facilities: Expert reviews are consistent in finding that there is no evidence of an increased risk of cancer associated with EfW facilities operated to current UK and European standards. As well as the reviews summarised in Section 2.4.1, the Associazione Italiana di Epidemiologia (2008) concluded that

> "*no clear evidence of risk linked to new generation incinerator plants has been highlighted so far.*"

Similarly, Reis (2011) concluded:

> "*a significant exposure of local populations to the most concern-raising pollutants from incineration processes is becoming ever more unlikely.*"

Other recent studies provide a consistent picture. Federico et al. (2010) carried out a study of the incidence of cancers within 5 km of the waste incinerator in Modena, Italy. Gouveia and Prado (2010) conducted a study of cancer incidence in populations within 7 km of a waste incinerator in Brazil. No increased risk of cancer was observed in either study, although Gouveia and Prado (2010) were not able to account for confounding factors such as smoking. Viel et al. (2008) reported an association between Non-Hodgkins Lymphoma and levels of dioxins, furans and dioxin-like polychlorinated biphenyls in blood serum. However, the authors were not able to identify the sources of these chemicals.

Risk from incinerators not subject to UK emission limits: A number of studies of cancer incidence have reported an association between cancer incidence and exposure to emissions from incinerator facilities. A number of these studies relate to facilities emitting substantially higher quantities of dioxins and furans and other pollutants than would be permitted in the UK (Comba et al., 2003; Floret et al., 2003; Tango et al., 2004; Viel et al., 2008; Zambon et al., 2007). This is because of the age, geographical location, and/or operating regime at the facilities. For example, Tango et al. (2004) studied waste incinerators in Japan with emissions more than 800 times the emission limit set in the Waste Incineration Directive. Similarly, the rate of emissions of dioxins and furans from industrial sources in the Venice area estimated by Zambon et al (2007) was more than ten times higher than the emissions of dioxins and furans from all MSW incineration facilities in the UK in 2009.

Consequently, the associations identified in these studies suggest that current facilities operating in the UK would have no detectable effects on cancer incidence in local populations. Furthermore, the studies of Comba et al. (2003) and Zambon et al. (2007) reflected exposure to a wide range of industrial sources, and were not limited to waste incineration facilities.

Strength of association: The World Cancer Research Foundation and American Institute for Cancer Research (1997) adopted a simple framework for evaluation of epidemiological studies. This is summarised in Table 1 below.

Table 1: Relative risk and judgements

Relative risk or Odds Ratio	Description
RR or OR is >2 or<0.5 and is statistically significant	Strong
RR or OR is >2 or <0.5 but not statistically significant	Moderate
RR or OR is between 1.5-2.0 or 0.5-0.75 and is statistically significant	Moderate
RR or OR is between 1.5-2.0 or 0.5-0.75 but not statistically significant	Weak
RR is between 0.75 and 1.5, whether or not statistically significant	No association

RR: Relative Risk OR: Odds Ratio

Following this framework as applied by Giusti (2009), only the association found by Zambon et al. (2007) would rank as "Moderate" – all other studies would be described as "weak" or "no association". As discussed above, the study of Zambon et al. (2007) relates to a wider range of sources of environmental emissions, and to much greater emissions of dioxins and furans.

Conclusion: In view of these considerations, and taking account of the uncertainty inherent in studies of this nature, it is concluded that EfW facilities as currently operated in the UK are most unlikely to have any significant or detectable effects on cancer incidence.

2.4.3 Infant mortality

Studies of the rates of infant mortality in wards surrounding EfW facilities have been made available (e.g. UKHR, 2009). These maps are interpreted to suggest that the rates of infant mortality are higher downwind of EfW facilities and lower upwind of EfW facilities. It is then suggested that the EfW facilities are the cause of the apparent increase in infant mortality.

These studies are flawed for a number of reasons.

1. In the cases which have been evaluated, there is in fact no clear pattern of higher rates in wards downwind (north-east) of the facility and lower rates upwind (south-west) of the facility. The actual pattern is more complex, and appears to be more closely aligned to aspects such as other sources of environmental pollution, or housing density. Further evaluation would be needed to draw definitive conclusions about these apparent correlations.
2. Similar patterns of infant mortality are observed in areas with no EfW facility.
3. If emissions from the EfW facilities were a significant factor in determining the rates of infant mortality, the pattern would not be as simple as a higher rate downwind of the facility and a lower rate upwind of the facility. Because the wind blows from all directions for some parts of the year, emissions from an EfW facility in the UK would typically affect areas to the north-east to the greatest extent, areas to the south-west to some extent, and areas to the north-west and south-east to a lesser extent. This pattern is also not reflected in the cases which have been evaluated.

It is concluded that claims of the effects of EfW facilities on infant mortality made on the basis of mapping studies of this nature should not be considered a matter of concern.

However, because of the profile given to this issue in recent years, AEA understands that the Health Protection Agency has proposed to carry out a study of infant mortality and other health issues in relation to waste incineration facilities.

2.4.4 Other adverse birth outcomes

A number of studies have investigated the potential effects of emissions from EfW facilities on adverse birth outcomes such as congenital abnormalities. The weight of evidence is that there is generally no detectable association between exposure to emissions from EfW facilities and birth outcomes, particularly when considering facilities operating to current European standards.

Tango et al. (2004) identified associations between dioxin exposure and risk of infant death. As described above, this study focused on facilities emitting dioxins and furans at levels 800 times higher than would be permitted in the UK. Cordier et al (2004) found increased risks for renal dysplasia and facial cleft in France associated with MSW incinerators operating between 1988 and 1997, during which time emissions of dioxins and furans and other substances were at much higher levels than presently permitted. This finding was also complicated by a separate association with traffic density

Cordier et al. (2010) identified an association between urinary tract birth defects diagnosed in 2001-2003 and exposure to emissions from EfW facilities. Again, this period reflects higher exposure than currently permitted, and the authors noted exposure to traffic pollution as a possible confounding factor.

Vinceti et al. (2008) studied population exposure to emissions from an incinerator in Modena between 2003 and 2006. This study found "*little evidence of an excess risk of adverse pregnancy outcomes in women exposed to emissions from a modern municipal solid waste incinerator.*" Specifically, no association was found between the incidence of adverse outcomes and maternal residence relative to the incinerator.

Lin et al. (2006) studied birth outcomes in populations living close to an EfW facility in Taiwan in 1997. The dioxin exposure levels under consideration were a factor of 10 or more higher than would be expected in relation to current UK EfW facilities. It was concluded that "*the incinerator generated dioxin poses little effects on birth weight and female birth, but might pose small effects on gestational age.*"

On the balance of evidence, and taking account of the uncertainty inherent in studies of this nature, it is concluded that EfW facilities as currently operated in the UK are most unlikely to have any significant or detectable effects on the incidence of adverse birth outcomes.

2.4.5 Respiratory disease

As reported by Health Protection Scotland/SEPA (2009), there is no evidence that EfW facilities have a significant or detectable effect on respiratory disease in local populations. The results of site-specific assessments for properly designed and located facilities (for example, those carried out during the planning and permitting stages) invariably confirm that no such effects would be expected.

2.5 Other waste thermal treatment techniques

A wide range of newer waste thermal treatment techniques are now being proposed and implemented in the UK. These include pyrolysis, gasification, and plasma gasification facilities. A number of other facility types include a combustion element such as anaerobic digestion in which biogas generated from the waste is typically burnt in a gas engine to generate electricity.

There is no published evidence in relation to the health effects of these thermal treatment facilities. Biogas engines have been in use on landfill sites for some time, but it would not be possible to distinguish any health effects associated with biogas engines from the health effects of other activities at the landfill site.

To the extent that some new waste thermal treatment technologies such as gasification give rise to comparable emissions to those from waste incineration, and would be subject to the same controls under the Waste Incineration Directive, no detectable health effects would be expected to occur, similar to current EfW facilities as set out in the preceding sections.

3 Conclusions

On the basis of the discussion above, it is concluded that emissions from EfW facilities would not be expected to give rise to any significant effects on health. Emissions from EfW facilities as currently operated in the UK are substantially lower than those from facilities operating prior to the implementation of the Waste Incineration Directive.

Taking account of the uncertainty inherent in epidemiological studies of EfW facilities, it is concluded that EfW facilities as currently operated in the UK are most unlikely to have any significant or detectable effects on cancer incidence, the incidence of adverse birth outcomes, or the incidence of respiratory disease.

Specifically, in view of the flawed methodology, it is concluded that claims of the effects of EfW facilities on infant mortality made on the basis of mapping studies should not be considered a matter of concern.

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AEA

The Gemini Building
Fermi Avenue
Harwell International Business Centre
Didcot
Oxfordshire
OX11 0QR

Tel: 0870 190 1900
Fax: 0870 190 6318

www.aeat.co.uk