An evaluation of the environmental and health impacts of residual waste treatments

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1. Introduction

The South West Devon Waste Partnership (SWDWP) is a partnership between Devon County Council, Plymouth City Council and Torbay Council. It has been established to deliver a sustainable long-term waste treatment solution for the communities of Plymouth, West Devon, South Hams, Teignbridge and Torbay.

Currently, two bidders remain in the process, each proposing a single treatment facility based on a Mass Burn Incineration (MBI) technology.

Understandably, there is an element of public concern and uncertainty about the effects that such a facility will have on both their local environment and on public health. This often provides a thrust for local groups who are opposed to Energy from Waste technology.

2. Aim

The aim of this report is to consolidate research that has been published regarding the environmental and health effects of waste treatment technologies. Specifically, it is intended to compare other waste treatment technologies to mass burn incineration (MBI), and to place all treatments in the context of total emissions released within the UK.

This report will be divided into an analysis of the main waste treatment technologies in the UK, including comparison of specific releases in tabular form where possible. The main sources for this document are the Department for Environment, Food and Rural Affairs (DEFRA) and also the Health Protection Agency, both of whom are referenced at the end of the report. Unfortunately, due to the lack of credible data for alternative thermal treatment technologies (Gasification, Pyrolysis and Plasma), it has not been possible to directly compare emissions from each technology.

It is important to note that there are no residual waste treatment technologies that do not have any impact on the environment. This message was clearly expressed in the Health Protection Agency's presentation to the Joint Working Committee in July 2010. One impact being traffic movements required to service such a facility. In addition, emissions will occur in some form from all current treatment technologies. However, the size of risk this presents has to be set in context.

3.0 Technology Evaluation

The technology evaluation is divided into three sections; i) landfill, the present residual waste disposal method in the Partnership area, ii) evaluating the conventional EfW solutions as proposed by the bidders and iii) alternative technologies that are comparable to incineration (see sections 3.3 and 3.4).

3.1 Landfill

The predominant method of residual waste disposal in the SWDWP area is landfilling or land raising operations. Waste is put into landfill 'cells' which are fully lined with a non-permeable lining. Liquid generated by the waste, known as 'leachate', is collected in lagoons and treated. Decomposing waste in landfill produces a significant quantity of emissions to air. Following the completion of a 'cell', that part of the landfill site is capped with an impermeable membrane and the gases given off are collected by a network of tubes throughout the landfill and used to feed either a flare or a gas engine to create electricity. It is not practically possible to capture all of the gases and some will leak into the atmosphere.

Landfilling has a significant environmental impact which occurs in many forms. Turning to emissions to the air in the first instance, this occurs through three primary methods;
1. Fugitive gas emissions through uncapped areas of the site, cracks or purpose built vents,
2. Emissions resulting from the combustion of gas via a flare and
3. Emissions resulting from the use of an energy recovery plant which uses a gas turbine to generate power.

Environmentally, the first element is by far the most damaging. DEFRA (2004) claim that 700,000 tonnes of methane are released from landfill sites every year, representing some 27% of total UK methane emissions. Due to methane's Global Warming Potential rating, this is one of the reasons why landfilling consistently compares poorly when considered against other residual waste treatments. Such comparisons are often made using tools such as the Environment Agency's 'Waste and Resources Assessment Tool for the Environment' (WRATE) analysis. Gas that is recovered from the majority of modern landfill sites is combusted and passed through an engine to produce electricity. This produces a variety of emissions to air. Emissions from each aspect of the landfill process are summarised in table 1:

Table 1: Landfill emissions

Substance	**Best estimate (g/tonne waste)**		
	Component 1 – Fugitive releases	**Component 2 - Flaring**	**Component 3 - Engine**
Nitrogen Oxides	Not emitted	100	900
Total Particulate Matter	No data	8	No data
Sulphur Oxides	Not emitted	120	70
Hydrogen Chloride	0.2	19	4
Hydrogen Fluoride	0.04	4	4
Total VOCs	25	1.7	No data
NMVOC	No data	1.9	30
1,1-dichloroethane	2.7	No data	No data
Chloroethane	1.0	No data	No data
Chloroethene	1.1	No data	No data
Chlorobenzene	2.4	No data	No data
Tetrachloroethene	3.3	0.008	0.2
Methane	75,000	400	2,000
Cadmium	Likely to be similar to engine	Likely to be similar to engine	0.1
Nickel	Likely to be similar to engine	Likely to be similar to engine	0.013
Arsenic	Likely to be similar to engine	Likely to be similar to engine	0.0016
Mercury	Likely to be	Likely to be	0.0016

	similar to engine	similar to engine	
Dioxins and furans	No data	74ng TEQ/T	190ng TEQ/T
Polychlorinated biphenyls	No data	No data	No data
Carbon Dioxide	130,000	220,000	350,000
Benzene	0.24	No data	No data

Source: DEFRA (2004) – compiled from a variety of sources within the report.

Detailed studies about the impacts that these emissions have on human health are limited. Instead, many studies appear to focus on emissions from hazardous landfill sites, often where no energy has been recovered. One study that is frequently referenced is by Elliott et al (2001) which explores the relationships between proximity to landfill sites and birth defects. Although a positive relationship was found, the study has been criticised for not taking into account any other factors, for example socio-economic variations.

The second impact that landfilling municipal waste has is on groundwater. Today, landfill sites are well contained with active leachate extraction which prevents the vast majority of contamination to groundwater and water courses. However, some seepage, especially during the landfill site's active period, is inevitable. Furthermore, when leachate is collected and sent to a sewage treatment works, this has its own environmental impact. The direct impact of seepage has been studied, but with no degree of conviction due to the unavailability of data which relates to quantity of leachate released.

3.2 Energy from waste

Energy from Waste facilities are seen as an effective method of diverting waste from landfill, as required by the Landfill Directive. Waste is combusted in controlled conditions with a surplus of air in order to ensure temperatures of over 850^0C. The HPA (2010) state this process causes three potential sources of exposure; via emissions, solid ash and cooling water. However, with proper management of the latter sources, the environmental impact of such a facility is almost entirely derived from its emissions to air. This is supported by DEFRA (2004) whose report offers just two paragraphs regarding any release to the sewer or surface water. This is because a facility discharges any liquid into the foul sewer network where it is later treated. This will have an environmental impact, but is insignificant compared with that resulting from a landfill site.

The EfW process also generates process residues, typically between 20% and 25% of input material. Much of this is 'Incinerator Bottom Ash' (IBA) which has a reuse value. However, the DEFRA (2004) report suggests that this inert material does produce a small further release when reused, although it has not been possible to validate this claim from other sources.

3.2.1 Air emissions

Energy from Waste technology during the 1980's and 1990's was not subject to as tight control as it is today. EfW technology has rapidly developed since the Waste Incineration Directive (WID) requirements came into force in the year 2000. Meeting the requirements of this directive requires more control on the combustion conditions maintained, combined with advancements in Air Pollution Control (APC) technology. Progress made improving emissions to air are clearly evidenced in the following table:

Table 2: Comparison of MBI emissions between 1980 and 2000			
Estimated Emissions to air (g/T of waste except where otherwise stated)			
Substance	**1980**	**1990**	**2000**
Nitrogen Oxides	1878	1580	1600
Total Particulates	313	264	38
Sulphur Dioxide	1421	1196	42
Hydrogen Chloride	3791	20	58
Hydrogen Fluoride	No data	No data	1
Volatile Organic Compounds	25	20	8
Cadmium	2.6	16	0.005
Nickel	2.8	28	0.05
Arsenic	0.40	0.33	0.005
Mercury	1.8	2.2	0.05
Dioxins and Furans	No data	0.00018g TEQ/T	4×10^{-7}g TEQ/T
Dioxin-like polychlorinated biphenyls	No data	0.0035g TEQ/T	0.0001g TEQ/T

Source: DEFRA (2004)

However, this is not to say that the EfW does not still have an environmental impact. In the first instance, EfW produces a substantial amount of carbon dioxide. DEFRA (2004) estimated that EFW facilities at the time produced around 2.4 million tonnes of CO_2 per year, 1 million of which resulted from fossil origins. As a result of the CO_2 emissions produced, EfW generally ranks lower on a WRATE analysis than alternatives such as MBT and AD, where a decreased proportion of waste is combusted. The WRATE analysis undertaken for the SWDWP only assessed an MBT solution with heat recovery, and compared to an EfW solution with heat recovery, produces approximately 15-20% less CO_2 per tonne.

However, despite this seemingly large figure, it only represented 1.6% of all UK CO_2 emissions. The CO2 impact can also be set in context against the substantial methane release from a landfill site, and this makes the solution more attractive when using a WRATE analysis. Emissions levels in general are also offset by power generation, particularly if a solution provides Combined Heat and Power (CHP). CHP solutions reduce the need for individual heat generation by end users which have a significant environmental impact. As illustrated by the WRATE analysis conducted for the SWDWP's outline business case in April 2008 (figure 1, over), a CHP solution can even result in an overall net reduction in CO_2.

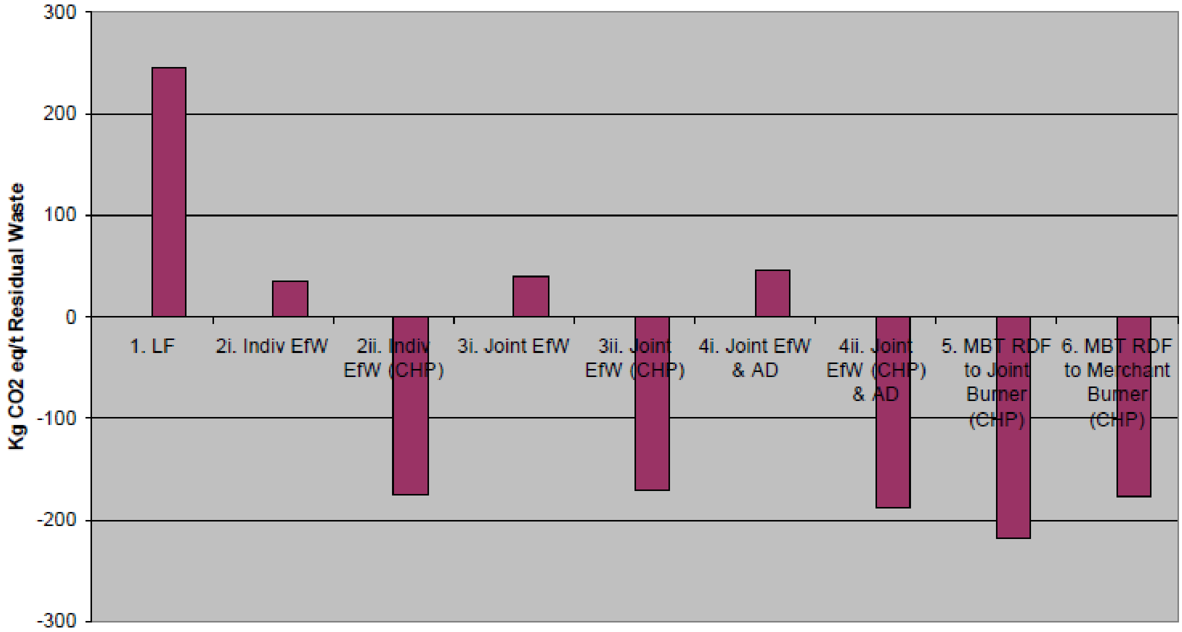

Figure 1: Extract from the SWDWP WRATE analysis showing CO_2 emissions from each evaluated technology.

Facilities which combust waste must meet the following WID limits:

Table 3: Adopted Waste Incineration Directive Limits	
Pollutant	**Maximum Allowance (per m^3 of release)**
Particulates	10mg
Volatile Organic Carbon Compounds	10mg
NO	200mg
HCl	10mg
HF	1mg
SO2	50mg
CO	50mg
Cd and Ti	0.05mg
Mercury	0.05mg
Lead (Pb), chromium (Cr) Copper (Cu), Manganese (Mn) Nickel (Ni), Arsenic (As), Antimony (Sb), Cobalt (Co), Vanadium (V), Tin (Sn)	0.5mg
N2O	30mg
NH3	10mg
Dioxins	0.1ng (TEQ)

In reality, most modern EfW facilities run well below most of these limits on a day to day basis. Many substances in the stack release are measured for the purposes of WID compliance and are measured on a continuous basis (daily or half hourly average). This allows operators to monitor the plant's performance in real time.

The health impacts of Energy from Waste have been extensively researched in recent years. At the time of their report publication in 2004, DEFRA acknowledged that *"Whilst incinerators generate a considerable amount of public concern, there have been few published epidemiological studies that examine the health of communities living in close proximity to them" (pg. 139)*. Instead, the majority of studies at the time focused on pre-WID compliant facilities. However, since 2004 a substantial amount of work has been carried out. The Health Protection Agency have compiled and reviewed these studies in a recently published report. Published in September 2009 and entitled "*The Impact on Health of Emissions to Air from Municipal Waste Incinerators*", the review concludes that "*While it is not possible to rule out adverse health effects from modern, well regulated municipal waste incinerators with complete certainty, any potential damage to the health of those living close-by is likely to be very small, if detectable.*"

3.2.2 Setting emissions in context

It is difficult to conceive how significant emissions from an Energy from Waste plant are. Tonne, gram, milligram or nanogram (TEQ) measures of different substances are intangible and cannot easily be equated into meaningful measures or direct impacts on human health which the public can understand. However, because emissions levels from EfW plants are so well documented, they can be broadly compared to those of other everyday activities. Some of the most frequently cited comparisons are sourced from a DEFRA paper (2007), entitled "Incineration of Municipal Solid Waste" which is intended to give a readable digest for the public. These include the following for a reference case of a facility processing 230,000 tonnes of MSW (not dissimilar to the solutions being considered by the SWDWP)

a. Oxides of Nitrogen – Equivalent to the production from a 7km length of UK Motorway (Data sourced from the DfT Design manual for roads and bridges). This measure is on an hourly basis, and is based on a measurement at the point of emission (i.e. taking no account of any dispersion to the atmosphere after release)..

b. Particulate matter – Equivalent to the production from a 5km length of UK motorway. (Data sourced from the DfT Design manual for roads and bridges). This measure is based on hourly production.

When one considers that the UK has in excess of 3,500km of motorway (Source: DfT, 2005), this is a good indicator of just how insignificant such a development is. Bridges (2008) claims that the development of a further 100,000 tonnes of capacity at the existing incineration plant in Nottingham will contribute a maxium of 0.05μg/m^3 of particulate into localised air with a concentration of between 44.9-51.3μg/m^3, and between 28-133μg/m^3 in typical office environments.

c. Cadmium – One twentieth of the emissions from a medium sized coal-fired power station in the UK. (Source: Environment Agency Pollution Inventory)

This statistic does not specify what constitutes a 'medium sized power station', but it is a useful statistic because it provides some indication about the effect on the environment and health that our existing energy infrastructure has.

d. Dioxins and Furans – Equivalent production to that of accidental fires a town with a population of around 200,000. The referenced town is Milton Keynes, which has a population smaller than Plymouth. (Source: National Atmospheric Emissions Inventory)

Dioxin and Furan releases are often referenced by concerned members of the public because there is technically 'no safe limit' for their release. However, it should be emphasised that they are produced in many everyday practices such as cooking, and that Municipal Solid Waste management accounts for just 1% of total UK dioxin and furan emissions (DEFRA, 2004). In turn, dioxins in the atmosphere (to which MSW incineration contributes 1%) are an insignificant form of human exposure, compared to some 97-99% of exposure caused by diet (Bridges, 2008).

3.3 Mechanical-Biological Treatment (MBT)

MBT is a hybrid disposal method which includes partial segregation of incoming waste into different fractions and some composting of organic material or processing by Anaerobic Digestion. Remaining material is landfilled or turned into a Refuse Derived Fuel (RDF) which is combusted.

a. Composting

Composting is a comparatively acceptable process to the public because it diverts waste from landfill to be processed for reuse. However, it does carry an environmental impact and may have an impact on human health. Composting produces Carbon Dioxide and small quantities of methane, both of which contribute to global warming. In addition, bioaerosols such as Aspergillus Fumigatus can be released when compost is agitated. Such microbes are known to have adverse effects on those who have conditions such as respiratory problems. Composting can also produce inhalable dust and Volatile Organic Compounds (VOCs) in low quantities. As a result of this, composting operations usually have to be sited over 250 metres from the nearest sensitive receptor (eg people) to satisfy Environment Agency requirements.

b. Anaerobic Digestion

Anaerobic Digestion has a comparatively low environmental impact. This is due to a) The completely airtight conditions in which the process occurs and b) The offset from power generated by the methane that is produced. As a consequence, its main impact is via emissions released when the methane is combusted. However, DEFRA (2004) have published very little detail about the effects of the AD process because, at the time of writing, there were no full sized AD plants in the UK using a municipal waste feedstock. Furthermore, AD cannot be classed as a residual waste treatment because it only addresses the organic fraction, leaving other material which still requires disposal.

c. Refuse Derived Fuel (RDF)

Unfortunately, the DEFRA study conducted in 2004 does not fully address the environmental and health impacts of an MBT system because there were no operations that addressed the whole residual waste stream in the UK at the time of publication. As a consequence, no data beyond ‘Total Emissions per Tonne’ was published. This appears to be a vague measure which takes no account of the combustion of an RDF fraction. It is therefore not surprising that this report is often used as a reference for groups who support MBT. The reality seems to be that very little information was available on the process at the time, and therefore the total impact of such a process is not documented adequately and has not been done so since.

3.4 Other residual treatment technologies

In addition to landfill, incineration and Mechanical Biological Treatment, there are a host of other technologies which are less established in the UK which are outlined below. The impact of these technologies has not been the subject of credible research to date. They are not adequately addressed in the 2004 DEFRA report, and subsequent work resulting from the 2010 DEFRA new technologies programme was inconclusive due to the failure of a new RDF pyrolysis plant at the point of commissioning.

3.4.1 Fluidised bed combustion

Fluidised bed combustion is an alternative to moving grate MBI, which provide the basis of the content for section 3.2. Waste is initially pre treated to remove metals, other recyclables and non combustible items. It is then shredded to produce an RDF product. Rather than a moving grate, shredded waste is passed over a moving ‘sand’ (or fluidised) bed which has air pumped through it.

3.4.2 Gasification

A gasification process can occur in either a low (700^0C – $1,000^0$C) or high temperature ($1,200^0$C – $1,600^0$C) system and uses a low oxygen environment. Gasification uses oxygen, but does not burn with a flame. The resulting ash is known as ‘char’.

Both low and high temperature systems produce a mix of gasses (syngas) which are suitable for power generation when used as a fuel for an engine or turbine. The high temperature system can produce a ‘biofuel’ product

3.4.3 Pyrolysis

This process treats MSW in the absence of oxygen (similar to smouldering wood to make charcoal) but sometimes uses steam.

Waste is crushed and loaded into a chamber where temperatures reach around $1,200^0$C. This heat breaks down the waste to produce syngas (for power) and ash (char).

3.4.4 Plasma

Plasma processes ultimately ‘melt’ waste and convert small amounts of residue into a stable glass like substance. The process claims to recover 99% of the input into clean gas (syngas) for energy generation and aggregate for use in industry.

Initially, waste is pre sorted to remove any recyclable or oversized material (such as mattresses). Waste is then gassified (fluid bed) at approximately 800^0C to produce gas and char.

The plasma process then uses very high temperatures and UV to break this gas and char down further to leave a small amount of residue requiring disposal, clean gas and aggregate.

Because of the thermal element involved with each of these technologies and their consequential emissions, they all need to meet the requirements of the WID. However, due to lack of research at present, their level of compliance is unknown with any degree of certainty. DEFRA’s data in this instance is acknowledged to be of moderate quality at best, and poor at worst. Indeed, the data provided is generic to gasification, pyrolysis and plasma technology. In reality the emissions release from each process are likely to vary considerably.

4. Conclusion

Mass Burn Incineration is a residual waste treatment technology which has very accurately been assessed for both impacts on the environment and on human health – it presents a known quantity. As a consequence, it is well documented that it could have an impact, no matter how small. It is unsurprising that this was the conclusion that the Health Protection Agency presented to Committee in July 2010. Despite a lack of information relating to alternative thermal treatments, modern EfW plants can be compared directly to landfill, and this has been done in the table below.

Table 4: Comparison of the emissions relased from a landfill site (with gas engine) and a modern EfW plant		
g/T unless otherwise stated		
	Landfill (with engine)	**EfW (modern)**
Nitrogen Oxides	900	1600
Total Particulates	No data	38
Sulphur Dioxide	70	42
Hydrogen Chloride	4.2	58
Hydrogen Fluoride	4.04	1
Volatile Organic Compounds	25	8
Cadmium	0.1	0.005
Nickel	0.013	0.05
Arsenic	0.0016	0.005
Mercury	0.0016	0.05
Dioxins and Furans	190ng	400ng
Methane	77,000	19

However, when set in the context of the infrastructure that are encountered in everyday life, it can be seen that the effects and risks are comparatively small. An EfW plant approximately the size of that proposed to the partnership will have a an environmental impact that can be equated to 0.2% of the UK motorway network (for Oxides of Nitrogen) or accidental fires from 0.3% of the UK population (for Dioxins and Furans).

As a known and well documented quantity, incineration can be made to appear to be a poorer option in comparison to other technologies. However, as this report has shown, this is often because very little is known, quantified or proven from these comparatively fledgling technologies. Simply reading the DEFRA review in 2004, the most recent study of this type, one could be persuaded that MBT offers a less damaging solution to residual waste management. The reality is that the report offers an incomplete picture of the process, which in operational terms varies considerably from that portrayed.

Reference list:

Bridges, J (2008). *Health impact assessment for the proposed third line extension of the eastcroft energy from waste plant*

Department for Environment, Food and Rural Affairs (DEFRA) (2004). *Review of Environmental and Health Effects of Waste Management: Municipal Solid Waste and Similar Wastes*. HMSO, London

Department for Environment, Food and Rural Affairs (DEFRA) (2007). Incineration of Municipal Solid Waste. HMSO, London.

Department for Transport (DfT) (2005). *Transport Statistics* [Online] Available from http://www.dft.gov.uk/pgr/statistics/ [Accessed 21/09/2010]

The Health Protection Agency (2010). The Impact on Health of Emissions to Air from Municipal Waste Incinerators. HPA, London.