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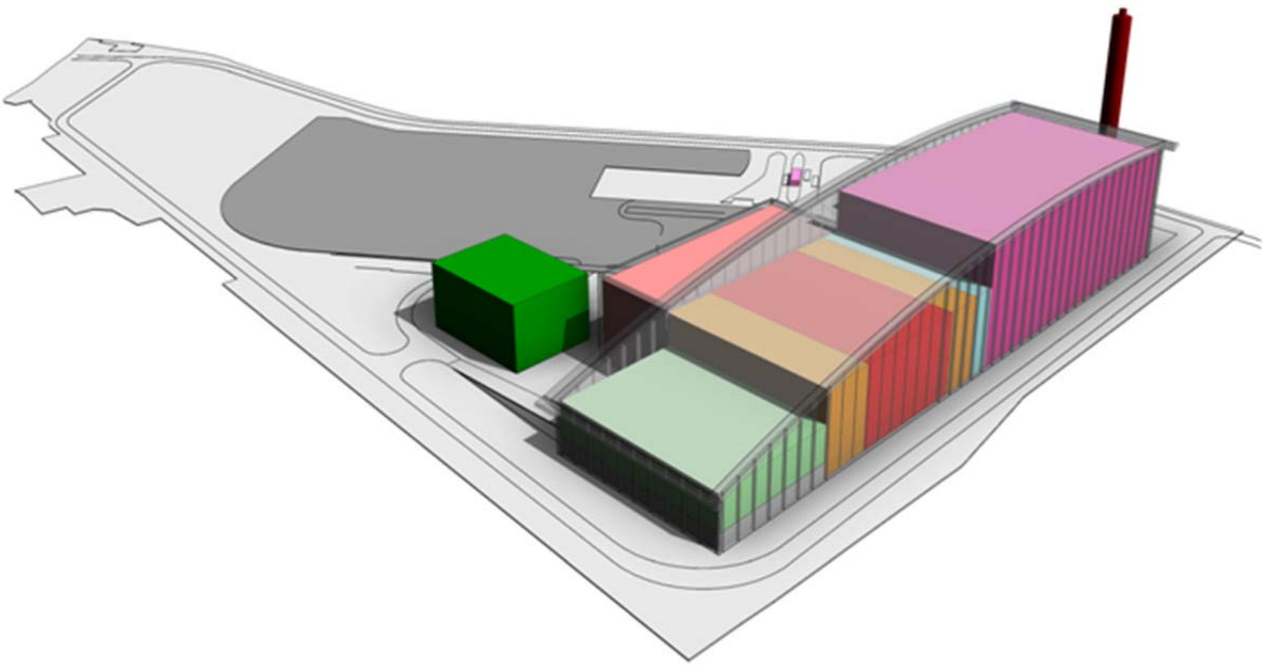
NORTH LONDON HEAT AND POWER PROJECT – HEALTH IMPACT LITERATURE REVIEW



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CONTENTS

1. EXECUTIVE SUMMARY

Municipal Solid Waste Incinerators (MSWI) or Energy recovery facility (ERF) emissions are often cited as a source of opposition to new facilities. Emissions from ERFs are tightly controlled under European legislation, specifically the Industrial Emissions Directive (IED). There are stringent limits for a number of potential pollutants, as well as demanding operating requirements that help minimise pollution.

The potential impact on health arising from emissions to air of ERFs has been the subject of a number of studies led by respected Public bodies, and other parties. In its review of these overarching studies, Ramboll notes that, whilst the focus of each study varies, the guiding principles and overall conclusions can be considered similar.

It has been established that emissions from ERFs are a minor contributor to local air quality in comparison with other typical activities such as traffic or industry. Modern ERFs are operated in a well regulated regime, reducing their potential impact compared with older plants. A direct association between modern ERF emissions and adverse health effect on the population has not been established.

Public Health England (PHE) is the UK Government's advisor on the impact on health of emissions to air from ERFs. In 2009 PHE has reviewed research undertaken to examine the suggested links between emissions from municipal waste incinerators and effects on health. It notes that modern, well managed, incinerators make only a small contribution to local concentrations of air pollutants. The PHE's view is that while it is possible that such small additions could have an impact on health, such effects, if they exist, are likely to be very small and not detectable.

PHE commissioned a study to further extend the evidence base as to whether emissions from modern ERFs affect human health. This is due to be published in 2015. Ramboll expects this study to support/confirm HPA's 2009 study conclusions.

2. INTRODUCTION

The impact of incineration on human health has been the subject of many debates and the focus of public interest in the UK and most European countries in the past decades. The general public perception in the UK is that energy recovery facilities (ERFs) can be a source of local pollution and this has, on occasion, been a major hurdle in the development of new ERFs.

The potential impact of incineration on human health has, as a consequence, been the subject of a number of studies from the scientific community and public organisations. This work has been undertaken to better establish the link between ERFs and potential health impacts.

Ramboll's review is a non-exhaustive review of selected studies, primarily considering the potential health impacts of existing ERFs on local population; these are documented in the report as follows:

- Emissions and Air Quality (Section 3)
- Health Impact literature reviews (Section 4)

A glossary of specialised scientific vocabulary used throughout this document is provided in **Appendix 3**. A glossary of typical ERF emissions is provided in **Appendix 4**.

3. EMISSIONS AND AIR QUALITY

3.1 Flue gas production

The combustion of solid fuel, including waste and waste derived fuel, results in the production of gases consisting of water vapour, carbon dioxide and excess air. This mixture of combustion gases is called "flue gas".

Approximately 75% of the flue gas is excess air, consisting of unburned oxygen and atmospheric nitrogen as well as argon (Ar) and other atmospheric components, are harmless and do not require any treatment. The balance of flue gas can contain small amounts of other components such as acidic gases, organic substances, trace heavy metals and fly ash particles that could, if untreated, potentially have adverse health and environmental impacts.

Flue gas composition and treatment is explained in detail in Ramboll's Flue Gas Treatment Technology Options Report. A glossary of emissions produced when combusting waste is set out in **Appendix 4**.

3.2 Regulation

Over the past sixty years, the regulatory requirements for ERFs have steadily increased. The requirement to capture and neutralise the compounds to the required standard is well understood and observed by the modern ERF industry. Established and proven systems are a pre-requisite to modern ERF facilities, preventing release of harmful substances into the atmosphere.

The major milestones in the development of the current emission regulations are listed in the following table. The implementation of regulations is often 'phased' with different compliance dates for plant operating or proposed at the time of adoption – operational plants may be gifted a period in which emissions must be reduced to meet the increasing stringent requirements. This should be noted when considering the results stated in historic health impact studies and the significant improvements in emission performance over time.

Table 1: Major milestones in the development of ERF emission regulations

Year	Regulation
1956	Clean Air Act
1970 - 80's	Clean Air Act amendments, Guidelines and individual permits
1989	Council Directive of 8 June 1989 on the prevention of air pollution from new municipal waste incineration plants (89/369/EEC) and Council Directive of 21 June 1989 on the reduction of air pollution from existing municipal waste-incineration plants (89 /429/ EEC)
2000	Waste Incineration Directive (WID), directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste
2006	BREF 2006, Best Available Techniques (BAT) Reference note, Integrated Pollution Prevention and Control - Reference Document on the BAT for Waste Incineration; August 2006
2010	Industrial emissions Directive (IED), Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on Industrial Emissions (Integrated Pollution Prevention And Control)
2016	Revised BREF expected

3.3 Emission levels

Defined in the IED, Emissions Limits Values (ELVs) prescribe limits for controlled pollutants emitted by ERFs in Europe. To meet these emissions limits, the combustion process must be suitably controlled and the flue gases treated prior to release from the stack.

The flue gas treatment (FGT) processes selected to achieve the required standards need to be in line with Best Available Techniques (BAT). In the UK, a common approach for control of emissions is formed by the following processes:

- Optimisation of combustion control, residence time and waste feed to minimise production of emissions;
- Ammonia or urea injection into the combustion gas for reduction of mono-nitrogen oxides (nitric oxide and nitrogen dioxide) (NOx) emissions;
- Lime or Sodium Bicarbonate injection for control of acid gas emissions (mainly sulphur dioxide (SO_2), hydrogen chloride (HCl), hydrogen fluoride (HF));
- Activated carbon injection for capture of trace heavy metals and dioxins; and
- Filter systems to collect fly ash and other solid residuals (lime or bicarbonate and activated carbon).

The table below illustrates the significant reduction in emission levels from ERF plants, driven by increasing regulation, and met by improvements in treatment technology and plant operation.

Table 2: Reduction in ERF emission levels over time

Components	Typical emission levels			
	Pre 1970	1980	2000	2020 *(potential)*
Particulates (mg/m^3)	500	150	5	1
Sulfur Dioxide (mg/m^3)	300	300	40	10
Hydrogen Chloride (mg/m^3)	500	500	10	5
Oxides of Nitrogen (mg/m^3)	400	400	200	100
Dioxins (ng/m^3)	4	4	0.1	0.05

As the figures shown in the above table (**Table 2**), emissions from ERFs have reduced significantly over the course of the last 40 years. Substantial reductions have been achieved since the 1990s. ERF emissions of the main pollutants under current regulations (IED and BREF) have been reduced by a factor of around 10 compared to the mid-1990s and by a factor of around 100 compared to previous decades, before any regulations were implemented. This applies to important pollutants such as particulate matter, hydrogen chloride (HCl), dioxin and most trace heavy metals. Other pollutants such as sulfur dioxide (SO_2) and of mono-nitrogen oxides (nitric oxide and nitrogen dioxide) (NO_x) have also reduced significantly.

This evolution must be taken into account when reviewing health impact studies. Health impact studies carried-out in the past, when higher emission levels from ERFs were allowed, may not be representative of the current situation.

Flue Gas composition and treatment techniques are detailed more thoroughly in Ramboll's Flue Gas Treatment Technology Options Report.

3.4 Performance and Reporting

Control of emissions is a key element of satisfactory ERF operations. Performance against ELVs is measured on a continuous basis, by calibrated instrumentation, with all data recorded and reported.

Quarterly extractive sampling is also undertaken to external third parties, who must also hold accreditation in emissions monitoring standards, to validate plant performance. The Environment Agency is issued reports on a Quarterly and Annual basis setting out plant performance, and is also notified on an ad-hoc basis of any breeches.

3.5 Air Quality

The impact of ERFs on air quality is a function of stack emissions and their dispersion. Air dispersion modelling is used to calculate the expected impact of a plant surrounding air quality. This modelling will also be carried out for the new Edmonton ERF to ensure that the impact on local air quality is acceptable. A new ERF with an appropriate stack height will only have a small effect on air quality (a small fraction of the EU limit values for air quality) and generally modelling shows that an ERF only contributes little to the general background levels.

Ramboll has reviewed the following Air Quality impact studies, as set out in **Appendix 2.**

1. Report on Air Quality in the Vicinity of SELCHP (2000) by Oakwood Environmental Services for CREED UK, Environment Energy and Waste Research Centre

2. Determinants of dioxins and furans in blood of non-occupationally exposed populations living near Portuguese solid waste incinerators (2007); M.F. Reis a, J.P. Miguel, C. Sampaio, P. Aguiar, J.M. Melim, O Papke published by Science Direct

3. Management of atmospheric pollutants from waste incineration processes: the case of Bozen (2013); M. Ragazzi, W. Tirler, G. Angelucci, D. Zardi and E. C. Rada published by Waste Management & Research

The above studies have concluded that air quality is more significantly impacted by traffic and other industrial activities than the operation of modern ERFs.

4. HEALTH IMPACT LITERATURE REVIEW

Ramboll has reviewed the following Literature and Evidence Reviews Commissioned / Published by Public Agencies. These studies are considered to be from authoritative organisations and take account of extensive publications and work assessing ERF health impacts.

1. Review of Environmental and Health Effects of Waste Management (2004); Enviros, University of Birmingham and Defra

2. Cancer incidence near municipal solid waste incinerators in Great Britain; COC statement COC/00/S1 and Update Statement on the Review of Cancer Incidence near Municipal Solid Waste Incinerators; COC/09/S2 by Committee on Carcinogenicity of Chemicals in Food, Consumer Product (2000 & 2009)

3. Systematic review of epidemiological studies on health effects associated with management of solid waste (2009); D Porta, S Milani, A I Lazzarino, C A Perucci and F Forastiere

4. The Impact on Health of Emissions to Air from Municipal Waste Incinerators (2009); Health Protection Agency

Appendix 5 lists over 60 publications on health impact of ERFs. The studies are by public authorities and bodies; recognised institutions and the scientific community. The table lists the above publications reviewed by Ramboll and highlights the studies covered by each publication we have reviewed. The table demonstrates the breadth of publications, ranging from literature reviews to case studies, our review has covered.

Ramboll has also performed a review of some of the case studies the above literature reviews have considered. This provides examples of detailed analysis undertaken to address public health concerns and sets out findings for reference. These studies are detailed in **Appendices 2** and **3** and are as follows:

Appendix 3: Health Impact Studies

1. Dioxin emissions from a municipal solid waste incinerator and risk of invasive breast cancer: a population-based case-control study with GIS-derived exposure (2008); J-F. V, M-C. Clément, M. Hägi, S. Grandjean, B. Challier and A. Danzon published by International Journal of Health Geographics

2. Long-term monitoring of dioxins and furans near a municipal solid waste incinerator human health risks (2012); L. Vilavert, M. Nadal, M. Schuhmacher and J. Domingo published by Waste Management & Research

3. Spatial analysis of health effects of large industrial incinerators in England, 1998–2008: a study using matched case–control areas (2012); F. Reeve, T. Fanshawe, T. Keegan, A. Stewart and P. Diggle published by BMJ Open

The UK Health Protection Agency (HPA), now part of Public Health England (PHE), is funding the Small Area Health Statistics Unit, Imperial College London, and the Environmental Research Group, King's College London. Both organisations are part of the MRC-PHE Centre for Environment and Health and have been commissioned to carry out a study to further extend the evidence base as to whether emissions from modern WERFs affect human health. The study covers distances of up to 10 to 15 kilometres from municipal waste incinerators (MSWIs)/ERFs located in England, Wales and Scotland. Scientists will research whether there is a potential association between emissions and the health of the population surrounding MSWI/ERF facilities. Potential effects investigated include: low birth weight, still births and infant deaths. Researchers will also investigate any possible link between municipal waste incinerator emissions and babies born with congenital anomalies.

A paper with preliminary results is expected to be prepared for submission to a peer-reviewed journal around the end of 2014, with publication in 2015.

The current position of the UK Health Protection Agency is indicated in the review of Paper 4 (*The Impact on Health of Emissions to Air from Municipal Waste Incinerators (2009); Health Protection Agency*).

4.1 Review of Environmental and Health Effects of Waste Management (2004)

4.1.1 Introduction and Background

This is a comprehensive study of the environmental and health impact of the various waste management options available for Municipal Solid Waste (MSW) and similar waste streams. The report was designed to inform and support waste management decisions and was initiated following a recommendation in the Strategy Unit report "Waste not, Want not: A strategy for tackling the waste problem in England". A subsequent commitment in the Pre-Budget Report 2003, Recommendation 15 of the Strategy Unit report stated 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."

The main purpose of this project was to review published literature together with any other relevant information and produce a compilation of information on emissions from MSW management facilities to air, land, groundwater, surface water and sewer. The information was provided directly by operators, taken from other research papers or extracted from the Environment Agency's Pollution Inventory. A total of 520 papers and other sources of information were reviewed. The report constitutes 420 pages containing valuable and practical information for making informed decisions on the development of new waste treatment and disposal facilities.

The report is by Enviros Consulting Ltd, University of Birmingham with Risk and Policy Analysts Ltd, Open University and Maggie Thurgood.

Ramboll's review focuses on the information and the findings related to waste combustion technologies.

4.1.2 Review of Information on Emissions

The report indicates that MSWIs/ERFs only use support fuels (e.g. fuel oil or gas) during start-up and that the majority of emissions are attributed to waste combustion.

The report provides estimated quantification of a wide-range of chemicals emitted to air and water, through both gaseous emissions and of ash residue production.

The report notes that ERF emissions of dioxins and furans, PCBs and trace metals from have decreased considerably since 1990.

4.1.3 Review of Epidemiological Research

Epidemiology designates the study of diseases in populations, as opposed to the clinical study of individual patients. Epidemiologic research typically seeks to associate exposure to a toxic substance with adverse health effects. This means that there must be some measure of exposure and also some measure of health outcome.

There are limited epidemiological studies examining the health of communities living in close proximity of ERFs. These studies tend to concentrate on the effects of exposure to emissions from older generation plants which have been progressively decommissioned.
The report includes details from the review of numerous publications organised under three distinct potential health effects:

- Cancer – "Despite reports of cancer clusters, no consistent or convincing evidence of a link between cancer and incineration has been published."

- Respiratory function – "To conclude, available studies have typically examined respiratory health around the older generation of incinerators. Most are based upon self-reported symptoms and therefore may be subject to bias (…). In many cases, air monitoring data do not demonstrate that emissions from the incinerators are a major contributor to ambient air pollution."

- Reproductive problems – existing literature covering the subject was reviewed but without drawing any definite conclusion. However, it is suggested that a direct association between human reproductive functions and ERF emissions could not be established.

Therefore, a detailed review of epidemiological studies related to ERF activities could not find consistent or convincing evidence of a connection between adverse health effect and incineration. Furthermore, it was concluded that ERFs only contribute to a small proportion to local pollutant levels.

4.1.4 Quantification of the Health Consequences of Emissions

The project team attempted to produce quantitative risk assessments. Predicted long term average emission concentrations were assessed in terms of adverse health consequences expressed in number of deaths brought forward per year; increases in number of respiratory cases per year and increases in cardiovascular cases per year.

The study identified that the most probable effect of emissions from an individual facilities is approximately one additional respiratory hospital admission in five years. On a national scale, at the time of publication, this would have corresponded to approximately four respiratory hospital admissions per year. The project team acknowledged that this estimate was reliable within a factor of 30.

4.1.5 Context for quantified health and environmental risks

The estimated health and environmental effects of MSW treatment and disposal options are put in context with other common polluting or potentially unsafe activities.

Distribution of UK emissions in context:

According to the report, MSW treatment and disposal activities were responsible for about 1% of the estimated UK total emissions of dioxins and furans. This figure was shared approximately equally between incineration and landfill gas combustion. The main sources of dioxins and furans were domestic emissions (i.e. cooking, heating, vehicles or garden lawnmowers) and fireworks, both of which account for about a sixth of total emissions. A number of other activities contributed to emissions of dioxins and furans at least as much as the MSW treatment industry, these include: accidental vehicle fires; small scale waste burning (e.g. on building sites); the iron and steel industry, the power industry or transport activities.

Road traffic equivalent of MSW management activities

A comparison can be made by considering how much road traffic would result in the equivalent emissions to those produced by the total of UK MSW activities. The national UK emissions of oxides of nitrogen from management of MSW were approximately equivalent to those emitted from traffic using a motorway 200 km (124 miles) in length. Likewise, emissions of particulates from management of MSW were approximately equivalent to emissions from a motorway 120 km (75 miles) long.

Health effects of MSW management

The following table compares the health effects of ERF emissions against other common activities.

Table 3: Comparison with other common activities

Deaths brought forward per year		Hospital admissions	
Road traffic accidents (2000)	3,409	Road traffic accidents (2000):	320,000
Accident at home	736	Accident at home:	168,300
Choking on food (2000)	246	Injury from firework (2002):	1017
Incineration emissions to air (estimated)	0.15	Hospital admissions:	4

Data Pedigree: Moderate quality

4.1.6 Conclusions

This work did not lead to the discovery of reliable evidence of significantly elevated levels of ill-health in populations potentially affected by emissions from ERFs.

UK ERF air emissions have reduced considerably over the past 20 years. This is in response to increasingly stringent legislation i.e. emissions of dioxins per tonne of waste from have decreased by 99.8% over this period.

The project team indicated that relatively reliable information exists for emissions to air from MSWI/ERF processes and that most emissions to air can be quantified with at least a moderate level of confidence, with a few exceptions. This allowed the production of calculation to estimate the probable health effects of some key pollutants emitted to air from waste management operations. Although the numerical estimates are of moderate or poor quality, they allow the project team to conclude that the probable health effects of these emissions are likely to be very small in comparison to those of other common and potentially hazardous activities.

4.2 Cancer incidence near MSWIs in Great Britain (2000 & 2009)

4.2.1 Introduction and Background

The Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment (COC) advises the UK government and government agencies on whether substances are likely to cause cancer. The COC has released 2 statements (in 2000 and 2009) regarding the potential of cancer incidence near MSWI/ERF facilities.

4.2.2 Cancer incidence near municipal solid waste incinerators in Great Britain; COC statement COC/00/S1 (2000)

The first statement by COC was released in 2000 and was based on a study from 1996 on cancer incidence near MSWIs in Great Britain conducted by the Small Area Health Statistics Unit (SAHSU)

At the time of the release of the first statement, eleven MSWIs were in operation in the UK, with another due to be commissioned shortly after production of the statement. The COC was also informed that the capacity for MSW in the UK was due to increase to meet the requirements of the proposed EC Landfill Directive setting limits for the part of biodegradable waste which could be landfilled.

The COC noted that a number of factors should be considered when deriving conclusions from the SAHSU studies:

i. accuracy of health statistics,
ii. accuracy of cancer diagnosis,
iii. potential confounding factors for individual cancers, and
iv. a number of environmental variables particular to incineration such as type of waste burnt, geographical and meteorological conditions, and controls placed on the emission of pollutants.

With regard to the SAHSU 1996 study of cancer incidence, the Committee was of the view that the excess of all cancers, stomach, lung and colorectal cancers were due to socio-economic confounding as has been reported by the SAHSU group. The analyses comparing cancer incidences prior to establishment of an incinerator with cancer incidences following a 10 year lag period after the start of exposure were consistent with this conclusion.

The COC's overall conclusions with respect to the SAHSU investigations can be summarised as follows:

1. It was not possible to conclude that the small increase in primary liver cancer observed was due to emissions of pollutants from MSWIs since residual socio-economic factors could not be excluded. Especially, it concluded that the excess of all cancers, stomach, lung and colorectal cancers were due to socio-economic cofounding.
2. The Committee agreed that there was no evidence of clustering near incinerators of cases attributed to angiosarcoma in a national register.
3. Any potential risk of cancer due to residency for periods in excess of 10 years in the vicinity of MSWIs "*was exceedingly low and probably not measurable by the modern epidemiological techniques*".

These conclusions are important, also since the assessment is based on study which reviews the impact on health during a period where the accumulated exposure to emissions from MSWIs/ERFs were significantly higher than would be the case for the same duration today.

4.2.3 Update Statement on the Review of Cancer Incidence near Municipal Solid Waste Incinerators; COC/09/S2 (2009)

The update statement released in 2009 provided a review of reports and epidemiological investigations on the subject published since 2000 and the new conclusions reached by the committee in view of the new publications reviewed.

In its updated statement, the COC indicated that new relevant epidemiological papers had been published since the 2000 statement was made.

The studies reviewed by the COC are listed in **Appendix 5**. A summary of the studies are provided below:

Childhood cancers, birthplaces, incinerators and landfill sites (2000); Knox, E. International Journal of Epidemiology

This study includes an analysis of the birth and death addresses of all children in Great Britain who had died of cancer between 1953 and 1980 and who had moved at sometime between birth and death. The study reported a greater incidence of cancer in children born close to incinerators and moving away than in those who were born further away and who moved closer to an incinerator. There was no information provided on the net migration of total population inwards and outwards from the vicinity of the MSWIs/ERFs.

Soft-Tissue Sarcoma and Non-Hodgkin's Lymphoma Clusters around a Municipal Solid Waste Incinerator with High Dioxin Emission Levels (2000) J_F Viel, P Arveux, J Baverel and J-Y Cahn American Journal of Epidemiology & (2) Dioxin emissions from a solid waste incinerator and risk of non-Hodgkin lymphoma (2003); N Floret, F Mauny,B Challier, P Arveux, JY Cahn, JF Viel. Epidemiology &.(3) Dioxin emissions from a municipal solid waste incinerator and risk of invasive breast cancer: a population-based case-control study with GIS-derived exposure (2008); J-F. Viel, M-C. Clément, M. Hägi, S. Grandjean, B. Challier and A. Danzon International Journal of Health Geographics

These studies investigating the population around Besancon (France) MSWI commissioned in 1971 and found to emit 16.3 ng ITEQ/m3 of Dioxin. The COC found that the first studies reported clusters of highly significant increase in cases of soft tissue sarcomas (STS) and Non-Hodgkin lymphoma (NHL) during the period 1980 to 1995. It acknowledged that the second study provided some evidence of an association between living near an incinerator and increased risk of NHL. In the third study the authors could not identify a positive association between PCDD/Fs and invasive breast cancer among women living in the area under the influence of the Besancon facility between 1996 and 2002

Risk for non Hodgkin's lymphoma in the vicinity of French municipal solid waste incinerators (2008); J.-F. Viel, C. Daniau, S. Goria, Pascal Fabre, P. de Crouy-Chanel, E.-A. Sauleau and P. Empereur-Bissonnet Environmental Health

This includes a French nationwide study prompted by the results from the two studies mentioned in the previous paragraph. It analysed the relation between cancer risk and past exposure to MSWIs/ERFs among neighbouring populations. The authors concluded that the study added further evidence to the link between NHL incidence and exposure to PCDD/Fs emitted by MSWIs/ERFs but that the findings could not be extrapolated to incinerators operating in 2008, which emitted lower amounts of pollutants.

Risk of soft tissue sarcomas and residence in the neighbourhood of an incinerator of industrial wastes (2003); P Comba, V Ascoli, S Belli, M Benedetti, L Gatti, P Ricci, A Tieghi Occup Env Medicine

A case control study evaluating the association between the incidence of STC in Mantua, Northern Italy, between 1989 and 1998 and residence near an incinerator of industrial waste reported a significant increase in the risk of STS occurrence associated with living within a 2 kilometre radius of an incinerator of industrial waste.

Sarcoma risk and dioxin emissions from incinerators and industrial plants: a population-based case-control study (Italy) (2007); P Zambon, P Ricci, E Bovo, A Casula, M Gattolin, A Rita Fiore, F Chiosi and S Guzzinati Environmental Health

This study evaluated sarcoma risk in relation to the environmental pollution caused by PCDD/F emissions from waste incinerators and industrial sources of airborne PCDDs and PCDFs within the Province of Venice (Italy). The increased risk of sarcoma in relation to both the duration and the extent of exposure was statistically significant.

The COC noted that in neither of the last two studies, there was any adjustment made for confounding factors.

4.2.4 Main Conclusions

Based on the further research in 2009, in its update statement, the COC concluded that:

"Although the studies indicate some evidence of a positive association between two of the less common cancers i.e. non-Hodgkin's lymphoma and soft tissue sarcoma and residence near to incinerators in the past, the results cannot be extrapolated to current incinerators, which emit lower amounts of pollutants. (...) Moreover they are inconsistent with the results of the larger study (...) carried out by the Small Area Health Statistic Unit".

The overall conclusion was therefore that there was "*no need to change the advice given in the statement produced in 2000 but that the situation should be kept under review*".

4.3 Systematic review of epidemiological studies on health effects associated with management of solid waste (2009)

4.3.1 Background and Method

The aim of this 2009 study conducted by a team from the Department of Epidemiology, Regional Health Service Lazio Region, Rome, Italy and the Division of Epidemiology, Public Health and Primary Care, Imperial College, London, UK was to systematically review the epidemiological literature on the health effects in the vicinity of landfills and incinerators and among workers at waste processing plants with a view to deriving a usable excess risk estimates for health impact assessment.

Relevant papers were found through computerised literature searches of MEDLINE and PubMed Databases. Peer-reviewed literature published between 1983 and 2008 addressing health effects of waste management was used. Each paper was examined in order to assess potential biases in the effect estimates produced. The evidence reported was graded with the associated uncertainties.

Twenty-one epidemiologic studies conducted on residents of communities with solid waste incinerators have been reviewed as part of this study:

- Eleven studies have been reviewed on cancer risk in relation to incinerators
- Six studies examined reproductive effects of incinerator emissions
- Four studies examined respiratory and/or dermatologic effects of incinerator emissions

The specific studies covered by this systematic review are listed in **Appendix 5.**

It is noted that, amongst all the studies reviewed, only one study included a period ending after 1998. All others are based on study periods ending in 1998 or before. In seven cases study periods ended in 1987 or before.

4.3.2 Review of critical studies

The publications considered by this review included the two studies below identifying a suspected link between MSWIs and health impacts. Ramboll has reviewed these studies in detail to set out their findings below as examples of critical health impact reviews.

1. Risk for non Hodgkin's lymphoma in the vicinity of French municipal solid waste incinerators (2008); J.-F. Viel, C. Daniau, S. Goria, Pascal Fabre, P. de Crouy-Chanel, E.-A. Sauleau and P. Empereur-Bissonnet published by Environmental Health.

2. Cancer incidence near municipal solid waste incinerators in Great Britain (1996); P. Elliott, G. Shaddick, I. Kleinschmidt, D. Jolley, P. Walls, J. Beresford and C. Grundy published by British Journal of Cancer.

4.3.3 Risk for non-Hodgkin's lymphoma in the vicinity of French municipal solid waste incinerators by Environmental Health (2008)

The study was completed following suspicion based on epidemiologic evidence of an increased risk for non-Hodgkin's lymphoma (NHL) in the vicinity of MSWIs releasing high levels of dioxin. The purpose of the study was to examine this association on a large population scale.

The study area consisted four administrative departments in France, divided into 2,270 block groups. NHL cases considered were diagnosed during the 1990–1999 period and aged 15 years or more. Cases were then individually associated to a block by residential address geocoding. An atmospheric dispersion model was used to provide an estimate of emissions in the vicinity of 13 MSWIs operating in the study area. Cumulative ground-level dioxin concentrations were also calculated for each group and 5 confounding factors were taken into account: population density, urbanisation, socio-economic level, airborne traffic pollution, and industrial pollution.

A total of 3,974 NHL incident cases were investigated (2,147 males and 1,827 females). A statistically significant relationship was identified at the group level between risk for NHL and dioxin exposure, with a relative risk of 1.12 for persons living in highly exposed areas compared to those living in slightly exposed areas. Population density appeared positively linked both to risk for NHL and dioxin exposure.

This study provided evidence of a link between NHL incidence and exposure to dioxins emitted by MSWIs. However, it was noted by the authors that study findings could not be extrapolated to modern MSWIs/ERFs, which emit lower pollutants than those released by the incinerators to which the subject population was exposed.

4.3.4 Cancer incidence near municipal solid waste incinerators in Great Britain by British Journal of Cancer (1996)

Cancer incidences amongst populations near 72 MSWIs in Great Britain were analysed using the Small Area Health Statistics Unit database. The periods covered were 1974 to 86 for England, 1974 to 84 for Wales and 1975 to 87 for Scotland. Case numbers were compared with expected numbers calculated from regionally adjusted national rates. Observed-expected ratios were calculated and tested for decline in relation to distances of up to 7.5 km from the MSWIs. The study was conducted in two stages: the first stage involved the study of the data for 20 incinerators; the second stage the remaining 52 facilities.

As shown on**Figure 1** it was found that there was a statistically significant decline in the risk of cancer incidence with distance from the MSWIs for all form of cancers: stomach, colorectal, liver and lung cancer. Among the findings revealed during the second stage, the excess from 0 to 1 km ranged between 37% for liver cancer and 5% for colorectal cancer.

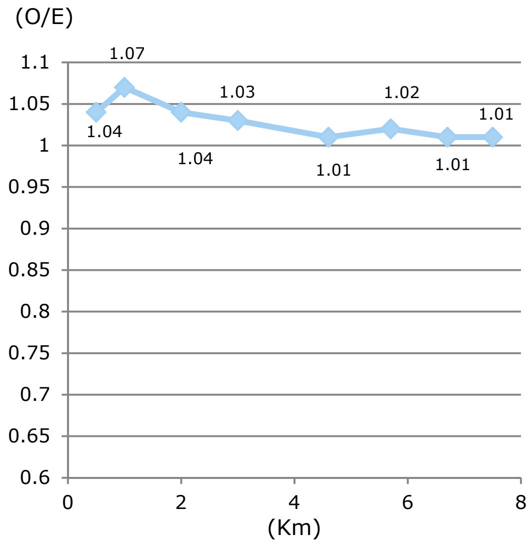


Figure 1: Ratio 10 year lag Observed (O) / Expected (E) by Distance for All Cancer Incidences

The study investigated cancer incidence potentially linked to exposure to pollutants emitted by older incinerators dating back to the turn of the 19th century. In addition, the authors noted that deprivation is commonly high in polluted areas and is strongly predictive of disease occurrence. In the authors' view, the strong socio-demographic and lifestyle effects associated with deprivation are likely to be greater than any effect of background pollution in those areas.

The authors concluded that the evidence of residual confounding factors found near the incinerators was a likely explanation of the findings of all cancer incidences. It also recommended that further investigation should be carried-out as this finding was based on routine cancer registry data, which may overestimate the true incidence of primary liver cancer because of mis-diagnosed secondary tumours. The authors suggested that further study could validate the diagnoses of primary liver cancer among cases included in this publication to more accurately determine the true excess incidence of liver cancer in the vicinity of MSWIs.

Based on the evidence collected by the scientific community and the fact that before the introduction of stringent ELVs, the control of emissions from old incinerators was limited, it seems possible that in some cases, the MSWI industry had a detrimental effect on the health of the population living in the vicinity of the facilities. However, it appears that even when an effect has been identified, the authors of the studies reviewed acknowledged that the results could not be directly extrapolated to current ERFs. Moreover, they also reported that significant confounding factors, in particular socio-economic aspects, were serious factors potentially reducing the significance of these findings

4.3.5 Results and Conclusions

The study reported the following results and conclusions:

- "*In most cases the overall evidence was judged to be inadequate to establish a relationship between a specific waste process and health effects; the evidence from occupational studies was not sufficient to make an overall assessment. For community studies, there was limited evidence of a causal relationship and a few studies were selected for a quantitative evaluation. For populations living within three kilometres of old incinerators, there was limited evidence of an increased risk of cancer, with an estimated excess risk of 3.5 percent. The confidence in the evaluation and in the estimated excess risk tended to be higher for specific cancer forms such as NHL and STS than for other cancers*".

- Furthermore, the authors of the paper concluded that "*the studies reviewed suffer from many limitations such as poor exposure assessment, ecological level of analysis and lack of information on confounding factors. Nevertheless, with a moderate level confidence, the authors have produced some effect estimates that could be used for health impact assessment of MSWIs. The uncertainties surrounding these numbers should be considered carefully when health effects are estimated*".

It is noted that the studies forming part of this systematic review are assessing the health impact of historical emissions from incinerators. Thereby, studying the impact of accumulated exposures to emissions from MSWIs during periods prior to the introduction of efficient flue gas cleaning when emissions were many time higher than those of a modern ERFs.

Section 3 outlines the developments in emissions from MSWIs over the years.

4.4 The Impact on Health of Emissions to Air from MSWIs, HPA (2009).

4.4.1 Introduction and Background

The Health Protection Agency (HPA) has statutory responsibility to advise Governments and Local Governments on the potential health impact of incinerators. HPA has reviewed studies examining the suggested association between MSWI/ERF emissions and effects on human health. This document was prepared by the HPA to communicate its knowledge and assessment of existing scientific evidence.

The incineration process can potentially cause harm to public health through three sources of exposure: (i) emissions to air, (ii) cooling water and (iii) solid ash residues. Assuming that the solid ash and cooling water are disposed of and handled adequately, air emissions are the only remaining route of exposure and the only source investigated in the HPA review.

The review is presented in the document according to pollutant categories and potential associations with health effects as follows:

Particles

Questions are often raised on the health effects of particles emitted by incinerators. The Committee on the Medical Effects of Air Pollutants (COMEAP) has published a series of reports and statements on the subject. It is accepted that exposure to current levels of air pollutants is affecting health. It is also accepted that short and long term exposures to particulates can damage health. No thresholds have been identified for either the effect of short term or long term exposure to increased particulate concentrations.

The mechanisms of particulates on health are not currently well understood but several hypotheses have been formulated, among others, they are likely to cause:

- The generation of free radicals in the respiratory system,
- The induction of an inflammatory response in the lungs,
- Effects on clotting factors in the blood,
- Effects on the development rate of atherosclerotic plaques in coronary arteries on the regulation of heartbeat.

There is also a possibility that heavy metals attached to particles play an important role in potential health impacts. Lack of understanding does not stop predictions of the effect from increased concentrations induced by the operation of MSWIs. Summary coefficients linking PM10 and PM2.5 with health effects applied to the small increase of concentration due to the MSWIs is estimated to be small, thus limited risks of exposed population health impacts.

According to data provided by Defra contributions of MSWIs to national emissions of particles is low. It estimated that in 2007 MSWIs only contributed up to 0.02% of the total national PM_{10} compared to 22% for production industries. This scale of magnitude is also found at local levels.

Carcinogens

There are two types of chemicals which have the potential to cause cancer: genotoxic carcinogens and non-toxic carcinogens. Genotoxic carcinogens induce cancer by reacting directly with the genetic material of cells and consequently by producing genetic mutations and are the main focus in air pollution studies.

Dioxins

Particular concerns have been expressed on the emissions of dioxins. The Committee on the Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) has recommended a tolerable daily intake of 2 pictograms WHO-TEQ / Kg body weight / day based on the most sensitive effect of TCDD on laboratory animals.

In view of the 0.1 ng per cubic meter emission limit for incinerators, direct respiratory exposure to dioxin is negligible in terms of the overall individual dioxins intake. More than 90% of the non-occupational exposure to dioxins occurs via food intake. Thus ingestion of locally produced food can be the main contributor. Calculations show that consuming a significant proportion of food produced/grown near incinerators only provides a small dioxin intake, well below the tolerable daily intake recommended by the COT.

Epidemiological studies: MSWIs/ERFs and cancers

The Committee on the Carcinogenicity of the Chemicals in Food, Consumer Products and the Environment (COC) has issued two statements in 2000 and in 2009 on the cancer epidemiology of MSWIs. These are reflected in Section 4.2.

- The first statement was made in 2000, after reviewing a large study by the Small Area Health Unit investigating cancer incidences between the mid-70s and the mid-80s amongst a population of 14 million within a 7.5 km radius of the MSWIs in Great Britain. The incinerators were of older generation and with many times air emission limits than modern ERFs. The COC concluded that: *"any potential risk of cancer due to residency (for periods in excess of 10 years) near to MSWIs was exceedingly low and probably not measurable by the most modern techniques"*

- In 2008 the COC reviewed seven studies published since 2000. All these had studied MSWIs of the older generation and three of the MSWIs were reported to have exceeded even older emission standards for dioxins emissions. COC's conclusion was*: "Although the studies indicate some evidence of a positive association between two of the less common cancers i.e. non-Hodgkin's lymphoma and soft tissue sarcoma and residence near to incinerators in the past, the results cannot be extrapolated to current incinerators, which emit lower amounts of pollutants. (…) Moreover they are inconsistent with the results of the larger study (…) carried out by the Small Area Health Statistic Unit"*. The COC indicated that there was no need to modify its previous advice but stated that the situation should be kept under review.

4.4.2 Main Conclusions

The HPA concluded its study by stating:

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

5. CONCLUSIONS

There are some public concerns in the UK over MSWI/ERF emissions and possible adverse human health effects. A significant number of studies have investigated this subject using a variety of spatial or statistical methods. These have been performed at area and individual levels as well as continuous and periodic samplings on various receptors i.e. human blood, soil, vegetation and air.

The publications reviewed by Ramboll are representative of the type of work completed to date on this subject. The scope of the studies set out below included analyses of the impact of incineration on air quality and human health.

1. Report on Air Quality in the Vicinity of SELCHP (2000) by Oakwood Environmental Services for CREED UK, Environment Energy and Waste Research Centre

2. Determinants of dioxins and furans in blood of non-occupationally exposed populations living near Portuguese solid waste incinerators (2007); M.F. Reis a, J.P. Miguel, C. Sampaio, P. Aguiar, J.M. Melim, O Papke published by Science Direct

3. Management of atmospheric pollutants from waste incineration processes: the case of Bozen (2013); M. Ragazzi, W. Tirler, G. Angelucci, D. Zardi and E. C. Rada published by Waste Management & Research

4. Review of Environmental and Health Effects of Waste Management (2004); Enviros, University of Birmingham and Defra

5. Cancer incidence near municipal solid waste incinerators in Great Britain; COC statement COC/00/S1 and Update Statement on the Review of Cancer Incidence near Municipal Solid Waste Incinerators; COC/09/S2 by Committee on Carcinogenicity of Chemicals in Food, Consumer Product (2000 & 2009)

6. Systematic review of epidemiological studies on health effects associated with management of solid waste (2009); D Porta, S Milani, A I Lazzarino,C A Perucci and F Forastiere

7. The Impact on Health of Emissions to Air from Municipal Waste Incinerators (2009); Health Protection Agency

8. Dioxin emissions from a municipal solid waste incinerator and risk of invasive breast cancer: a population-based case-control study with GIS-derived exposure (2008); J-F. V, M-C. Clément, M. Hägi, S. Grandjean, B. Challier and A. Danzon published by International Journal of Health Geographics

9. Long-term monitoring of dioxins and furans near a municipal solid waste incinerator human health risks (2012); L. Vilavert, M. Nadal, M. Schuhmacher and J. Domingo published by Waste Management & Research

10. Spatial analysis of health effects of large industrial incinerators in England, 1998–2008: a study using matched case–control areas (2012); F. Reeve, T. Fanshawe, T. Keegan, A. Stewart and P. Diggle published by BMJ Open

None of the above studies could establish or even suggest a definite association between the emissions of incinerators and adverse health effects on the local population. The studies have a limited capability to account for confounding factors such as socio-economic, meteorological and other sources of emissions. The body of literature generally does not support concerns about adverse health effects caused by proximity to modern MSWIs.

Limited studies have reported a possible link between older facilities and adverse health effects. Ramboll has reviewed:

- Risk for non Hodgkin's lymphoma in the vicinity of French municipal solid waste incinerators (2008)

- Cancer incidence near municipal solid waste incinerators in Great Britain (1996);

The above studies relate to exposure periods that pre date current emissions control technology and stringent legislative requirements. Modern ERFs employ extensive flue gas treatment technologies and concentrations of emission are a fraction of dated plants, most of which have been decommissioned or upgrade to comply with current legislation.

Findings from literature and evidence reviews carried out on behalf of public organisations are consistent with the case studies reviewed. Generally the conclusions can be summarised as follows:

- MSW Incinerator contribution to local air pollution levels is minor in comparison to other activities such as traffic, local heating sources or emission intensive industries.

- Older incinerators have been a potential source of pollution and may have contributed to adverse health impacts. However, emissions from modern, well operated ERFs in Europe have significantly decreased over the past decades in response to increasingly stringent regulations.

- No direct correlations between emissions from modern ERFs and adverse health impacts have been established. Whilst potential adverse health impacts of MSWI/ERFs on the population living in the vicinity of the facilities cannot be completely discounted, the fact that it could not be detected strongly suggests that the impact is negligible.

- In 2009 The Health Protection Agency (HPA) (now Public Health England (PHE), which has statutory responsibility to advise Governments and Local Governments on the potential health impact of incinerators) reviewed studies examining the suggested association between MSWIs emissions and effects on human health. PHE concluded that *"Modern, well regulated incinerators make only a small contribution to local concentrations of air pollutants. It is possible that such a small additions could have an impact on health but such effects, if they exist, are likely to be very small and not detectable."*

- PHE commissioned a study to further extend the evidence base as to whether emissions from modern ERFs affect human health. This study is due to be published in 2015. Ramboll expects this study to further support/confirm PHE's 2009 study conclusions.

The public concerns about health impacts from MSWI/ERF operations are primarily connected with emissions to air. The impact from emissions is mitigated by the treatment of combustion gases. Emissions include dust, acidic gases, trace heavy metals and dioxins. The operators of ERFs continually monitor key emissions to ensure compliance with permitted levels. Certain pollutants have to be monitored on a periodic basis. The monitoring is reported to the industry regulator, the Environment Agency, in accordance with the Environmental Permit. Modern flue gas treatment systems can achieve lower emission levels than those set in the typical Environmental Permit. This provides confidence that a modern ERFs will not have an adverse impact on health. The studies reviewed in this report indicate that emissions from vehicles have the most significant impact on air quality, whereas impact on air quality from MSWI/ERFs is considered negligible.

6. APPENDICES

6.1 Appendix 1 – Air Quality Impact Studies

6.1.1 Report on Air Quality in the Vicinity of SELCHP, 2000

Background Information

The South East London Combined Heat and Power Ltd (SELCHP) funded an independent survey of the impact from the facility's air emission on the local environment in order to address the general concern/fear of the local community.

The study was prepared by Oakwood Environmental Services, a consultancy specialising in monitoring ambient and stack emissions from a range of processes and subsequently advising their clients on the impact of their emissions.

The SELCHP facility is located in North Lewisham, London and receives over 400,000 tonnes per year of MSW from the London Boroughs of Lewisham, Greenwich and Bexley as well as from Westminster City Council. The plant consists of two identical processing lines, each with a capacity to process 29 tonnes of waste per hour.

Air quality was measured at the Baltic Wharf maintenance depot, a site located approximately 1 km from the SELCHP facility. The total test period consisted of four weeks – two weeks during which the plant was operational and two weeks when the plant was subject to planned maintenance work and not in operation. Measurements during facility shut down were used to establish the background air quality. The Baltic Wharf site was selected, as it is North East of the site and the winds are predominantly south westerly, so is likely to be exposed to any emissions.

The measurement programme was extensive and included all parameters regulated by the EU incineration directive except HF – these include trace heavy metals and dioxins. Wind direction and wind speed were also measured to ensure that the measurement equipment was placed directly downwind from the facility for a significant part of the testing period.

The monitoring programme was performed between 25th August and 21st September 2000, using a mobile laboratory equipped with continuous on-line instrumentation together with additional extractive equipment (weekly samples) for:

- hydrogen chloride (HCl),
- polycyclic aromatic hydrocarbons (PAHs),
- dioxins and furans (PCDD/Fs),
- trace metals,
- total suspended particulate matter (TSP) and
- vapour phase mercury (Hg).

Main Results and Findings

Generally, air pollution levels according to the Department of Environment Transport and Regions (DETR) Air Quality bandings at the location were low with respect to sulphur dioxide, nitrogen dioxide, PM10 and CO. None of the measured parameters exceeded the limit levels (at the monitoring site 1 km from facility) for any of the parameters regulated by the Industrial Emission Directive 2010/75/EC (which has absorbed the former Waste Incineration Directive, 2000/76/EC)

The findings of the monitoring programmes included:

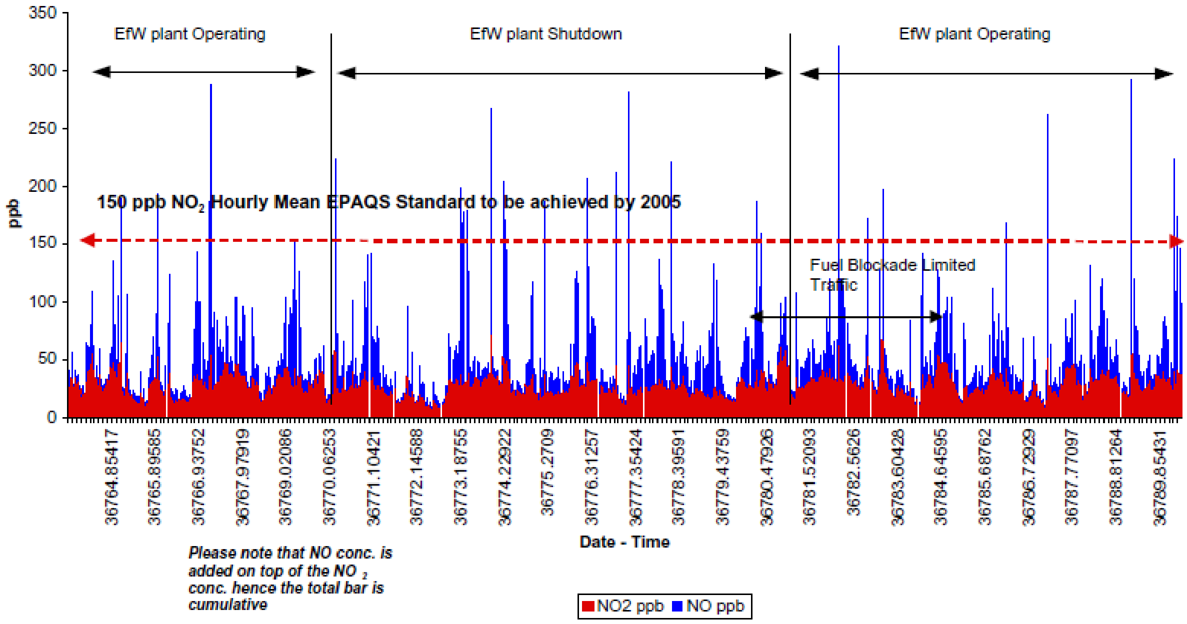
- Trace Metals: Measured concentrations of trace metals-in-air measured over the period were all well within the relevant air quality guidelines. Statutory limits did not exist at the time of publication for trace metals except for lead (0.5 µg m^{-3}), but guidelines were available from the World Health Organisation (WHO) for some and others were derived from occupational exposure guidance for the purpose of the study. The mean measured values of Total Heavy Metals for each of the 4 weeks monitored were as follow: 195, 159, 287 and 184 ng m^{-3} (arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), manganese (Mn), nickel (Ni), antimony (Sb), tin (Sn), thallium (TI) and vanadium (V) in the particulate phase)

- PCDD/Fs: The mean concentration of total PCDD/Fs at the Baltic Wharf Depot was 18 fg I-TEQ m^{-3} over the four-week period. The value was approximately 25% lower than the concentrations previously measured in London since 1996 with a 3 year mean of 26.4 fg I-TEQ m^{-3}.

- PAHs: Concentrations of individual PAHs measured over the four weeks period were found to be well within the range of annual mean concentrations measured at a background urban reference site located in London between 1991 and 1997 reported by the National Environmental Technology Centre (NETCEN). The level of benzo[a]pyrene was always below the Expert Panel on Air Quality Standards recommendation of 0.25 ng m^{-3}, with levels ranging from 0.14-0.20 ng m^{-3}.

Nitrogen dioxide, sulphur dioxide, carbon monoxide and PM10s: The standards and guidelines used for the above species were drawn from the EU, World Health Organisation (WHO), Expert Panel on Air Quality Standards (EPAQS) and National Air Quality Standards (NAQS). Some values were also compared to monitoring data from Eltham urban background site at the Ecology Centre, Bexley Rd (A210) even though the Baltic Wharf Site is considerably more industrialized and 4 miles North West of the Eltham site.

- NO_2: Nitrogen Dioxide was found to be below all six limits or guide values except for one guidance value which was slightly exceeded. This was the EU guide value as the 50th percentile of hourly means measured over one month (53.2ppb compared to 50ppb).



Source: Oakwood Environmental Services (2000)

Figure 2: Measured Concentrations of Oxides of Nitrogen

- SO_2: Concentrations of sulphur dioxide measured at the Baltic Wharf site were low and considerably below any EU guidelines or standards. With regard to DETR banding levels, the air pollution was classified as low for all 2,548 or 100% of the readings i.e. all levels were below 100 ppb (267 μg m^{-3}). The mean concentration of 3.74 g m^{-3} was well within the normal range of annual mean concentrations reported in the East Thames by the Quality of Urban Air Review Group (1993) Urban Air Quality in the UK.

- PM10s: The highest 24 hours running mean concentration measured of Fine Particulate Matter was 27.4 g m^{-3} was lower than the EPAQS and NAQS standards and guidelines. The highest 1-hour concentrations of 59.4 g m^{-3} was measured during a rush hour period and the slight elevations of other pollutants (NO, NOx, Total Hydrocarbons, CH_4 and CO) suggested that motor vehicles were the cause of the peak. Peaks also occurred during a period of light winds (<0.3s^{-1}). The report also indicates that peak times corresponded with peaks observed at the Eltham site.

- Total Suspended Particulate (TSP): The mean TSP concentration over the four weeks was 46 g m^{-3} was found to be well within the EU directive limit of 150 g m^{-3}. The mean PM_{10} concentration was 14.0 g m^{-3}, about 30% of the TSP concentration.

- CO: Carbon monoxide levels were generally moderate and peaks corresponded mainly to rush hour periods. According to the authors, the large refuse trucks coming and going from the depot where the measuring station was located probably also contributed to the measured levels. The maximum 1-hour mean level was 1.90 mg m^{-3} (1.63 ppm) with a mean level of 0.26 mg m^{-3} (0.22 ppm). The maximum 15-minute concentration was 2.38 mg m^{-3} while the WHO guideline level was set at 100 mg m^{-3}. The maximum 8-hour running mean concentration was 1.31 mg m^{-3}, considerably below the NAQS and EPAQS standards values set 11.7 mg m^{-3}.

- HCl: Concentrations of hydrogen chloride measured at the site ranged from 0.20 to 0.33 g m^{-3}, with a 4-weeks mean value of 0.27 g m^{-3}. These concentrations were below the Environmental Assessment Levels provided by HMIP/EA (Her Majesty's Inspectorate of Pollution) of 7 g m^{-3} at the time. The report also mentioned that the measurements were similar to background levels ranging between 0.3 to 1.1 g m^{-3} recorded in Essex (Harrison R M and Allen A G (1990) vol. 24 p 369-376.)

Main Conclusions

The measurement undertaken for the study did not show significant differences when the SELCHP facility was or was not operating. Furthermore, the correlation observed between the peaks of CO, NO2 and PM10 at rush hours (08:15 – 09:15) suggested that pollution levels mainly originated from ordinary vehicle emissions.

The above was further supported by the fact that other measured pollutants levels (SO_2, dioxins/furans and PAHs) were low, when compared to published data for other monitoring sites around the London Area presented in the report.

The general air quality at Baltic Wharf was similar to background measurements at other locations around 5 miles away. This indicates that the general air quality is determined by regional/national sources rather than local sources and also confirmed that emissions from the SELCHP facility are not a major source of pollutants in this urban context.

6.1.2 2007 - Determinants of dioxins and furans in blood of non-occupationally exposed populations living near Portuguese solid waste incinerators

Introduction and Background

Human biomonitoring is an effective tool to assess population exposure to pollutants. It provides a method to assess human exposure and potential health effects of such exposure more accurately than analysing the quality of the environment as such through air, water, food and soil monitoring programmes. Biomarkers are more directly linked to the adverse health effects. However, it is not providing information a priori on the exposure-health effects link.

Among the thermal combustion processes, solid waste incinerators were identified as a significant source of dioxins between the 1980s and early 1990s. They can release PCDDs and PCDFs which are resistant to both biological and chemical degradation and are lipophilic substances. These compounds bio-accumulate in the food chain, mainly in the lipids, increasing the potential hazard for humans.

Portugal has been developing specific surveillance programs to assess the potential impact of MSWIs on the environment as well the populations in the vicinity of the facilities. In relation to the activity of two MSWIs, Environmental Health Surveillance Programs have been launched and several human biomonitoring projects have been implemented, some of them investigating dioxins and dioxin-like compounds within the population potentially affected. The following two MSWIs were investigated:

- VALORSUL is a MSWI operating since 1999 in the urban area of North-Lisbon, in Portugal.
- A MSWI operational since June 2002 located in the island of Madeira. The facility processes solid waste from municipal, hospital and slaughterhouse sources.

The population under examination was made of apparently healthy, 18 to 65 years old volunteers, not occupationally known exposed to dioxins, residing in areas for more than one year. Within both populations (Lisbon and Madeira) the participants were classified as exposed and control populations. In total, 138 apparently healthy adults were studied relatively to dioxin body burden, 33 and 85 from Lisbon, during the first and the second observational period, respectively, and 20 from Madeira.

Seven dibenzodioxin, and ten dibenzofuran congeners were analysed by high resolution gas chromatography coupled with high resolution mass spectrometry. Statistical analyses were performed with SPSS software version 12.0 for Windows. Both protocols described have been approved by the Ethics Committee of the Lisbon Faculty of Medicine.

In Lisbon, during a preliminary phase, baseline levels of dioxins were measured in blood from subjects living in the area under potential influence of the facility and, for comparison, from individuals with farther place of residence and work. Additional measurements were made during the first two years, to monitor space and time trends.

On Madeira Island, baseline levels were established and examinations were repeated to enable an evaluation of a possible impact from the upgraded solid waste incinerator on human exposure to dioxins. The main results have been subject of another specific publication (Reis et al., 2004a,b; Sampaio et al., 2004a,b). The overall conclusion pointed to a non-significant regional difference on dioxin levels between exposed and control populations relative to each incinerator. It also suggested that dioxin exposure of global populations could not be associated to the emissions from the facilities investigated and that dioxin control technologies installed were effective in relation to both incinerators.

Main Results and Findings

The results were analysed to identify the differences in PCDD/Fs concentration in terms of area of residence (exposed vs non-exposed), community (Lisbon vs Madeiras), age, sex. This review mostly reports the findings obtained from the exposition factor.

- The analysis of PCDD/F blood levels, in pg WHO-TEQs per gram of fat, provides a comparison across areas of residence, communities and sex, as well as a correlation between age and dioxin levels. From the results, it was found that there were no statistically significant differences between exposed and non-exposed individuals. The findings were deemed to be interesting for the purpose of the investigation, since they suggested that the prior conclusion that the dioxin control systems of the incinerators of Lisbon and Madeira Island were effective, was accurate.

- PCDD/F levels in women showed a slightly higher trend although differences were not statistically significant.

- Individuals residing in Lisbon showed higher median PCDD/F levels when compared with those from Madeira (15.4 and 9.6 pg WHO-TEQ/g fat, respectively). The levels measured in Lisbon community may be attributed to different sources which are not present or not so intensive in Madeira. It should be noted that even though Lisbon was associated with higher dioxin levels, the extreme levels were similar between the two communities.

- In normal circumstances, diet is the major pathway of human dioxin exposure. However, analysis performed on the diet of both groups in a separate study did not suggest a statistically significant difference in relation to dioxin exposure from the most significant foodstuffs. Therefore, it can be assumed that the dioxin body burden in Lisbon might be due to higher dioxin emissions from industry sources and traffic.

- The analysis also identified a statistically significant association between the total TEQs in blood and age. As expected, elder individuals showed higher PCDD/F blood levels.

Further analyses were performed to investigate potential influencing factors on blood dioxin levels using bi-variable analysis and through the multiple logistic regressions. The influencing factors examined were professional activity and hobbies potentially leading to higher exposure, present or past smoking habits, intake frequencies of fruit and vegetables, and preferential consumption of meat or fish.

The results confirmed the importance of age as well as the association between Lisbon community and dioxin levels above median. Most importantly, it also confirmed in statistical terms, the dioxin emissions control effectiveness already suggested earlier. No statistical association between control and area of residence exposed to emissions of the MSWI and higher dioxin blood levels could be identified.

The results of repeated measurements during the different observational periods on the Lisbon population showed a relative homogeneity in the median and mean terms WHO-TEQ/g fat that provides further indication on the effectiveness of the Lisbon incinerator air pollution control system over time. The main values are indicated in the following table.

Table 4: Mean and median values of WHO-TEQ/g Dioxins Levels in blood for year 1 and year 2 in the Lisbon population.

	Median	Mean
Year 0 – baseline	14.6	15.5
Year 1	14.1	14.6

Main Conclusions

The paper does not contain a section summarising the conclusions of the work completed. However the authors mention that the results suggest that incineration does not impact blood dioxin levels of nearby residents.

Individuals from Lisbon showed higher median PCDD/F levels. The reason behind this is more likely to be that Lisbon is a more polluted area rather than eventual differences in dietary habits of the two groups. In fact, analysis performed on the diet of both groups (not detailed in the study) did not show a statistically significant difference in relation to any of the most relevant foodstuffs in the context of dioxin exposure.

6.1.3 Management of atmospheric pollutants from waste incineration processes: the case of Bozen, 2013

Background

This paper was published in the Waste Management & Research magazine issued by the International Solid Waste Association and was prepared by Marco Ragazzi, Werner Tirler, Giulio Angelucci, Dino Zardi and Elena Cristina Rada. It presents the case study of a waste incinerator located in a region rich in natural and environmental resources, and close to the city of Bozen, Italy. The facility consisted of two parallel lines with a total treatment capacity of 400 tonnes MSW per day. Flue gas cleaning was performed by a fabric filter and a two-stage wet scrubber, together with a final selective catalytic reduction unit for nitrogen oxides and trace organics removal.

Tto understand the effect of the facility on human health and the surrounding environment, the local authority adopted special measures to monitor the incinerator emissions. In 2003, an automatic sampling system was specifically installed to continuously sample polychlorinated dibenzodioxin/dibenzofuran PCDD/F emissions. The sampling system was coupled directly to aerosol spectrometers to determine fine and ultra-fine particle concentrations from the 50 m plant stack. Particulates and PCDD/F are substances of particular concerns due to their recognised potential to affect human health. Study results were used by the local decision-making process aimed at implementing a new plant to replace the existing facility, the subject of the study.

This article reports and discusses the results of the multi-year activity. Emission control of PCDD/F has taken place since 2003 when the automatic sampling system was installed to continuously measure emissions from the stack. Emission control of PCDD/F was performed during two sampling campaigns (August and September 2006 and later between December 2006 and January 2007). Typical wind conditions have been taken into consideration to identify two main deposit sites on the basis of previous numerical modelling assessment. Accordingly they were identified to be located South and North of the facility. Two and three directional samplers were used for the purpose of the respective first and second campaigns. A third sampler was installed in the centre of Bozen during the second campaign, an area which is not directly influenced by the incinerator's emissions.

Main Results and Findings

- PCDD/F - First Sampling Campaign

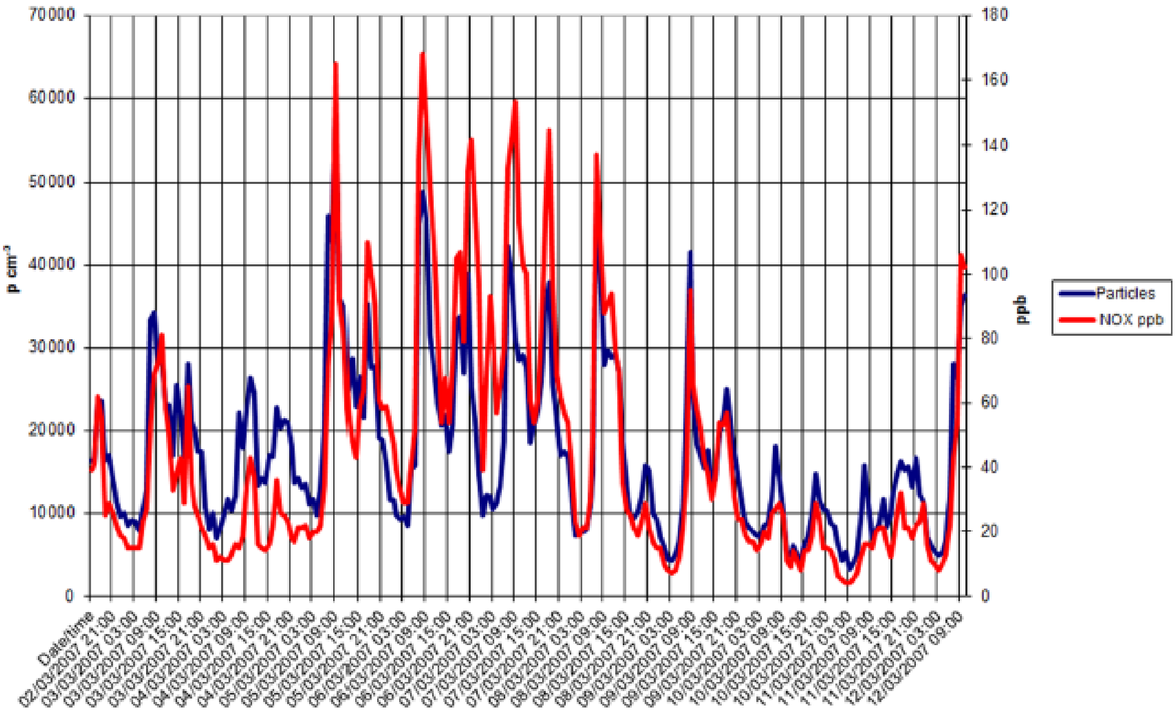
The short term PCDD/F emissions measurements (8h) at stack level ranged between 10% to 80% of the Waste Incineration Directive compliance emission limit value which is 0.1 ng I-TEQ / Nm^3. Emission values showed that values were all less than or equal to 20 fg TEQ m^{-3}. The 20 fg TEQ m^{-3} value was measured with northerly wind at the southern sampling point.

- PCDD/F - Second Sampling Campaign

Results from the second campaign showed that the influence of the plant on the PCDD/F in the urban area of Bozen could not be detected. PCDD/F air concentrations were comprised between 79 and 90 fg TEQ m^{-3} at the Northern sampling point and between 52 and 84 fg TEQ m^{-3} at the southern sampling point. The highest value was measured at the north sampling site under northerly winds. At the third site, not exposed to the main contribution of the plant, the measured concentrations ranged from 155 to 259 fg TEQ m^{-3}.

- Particulates Matter

The data collected showed that in the southern sampling site, when the wind blows from the south, the PM concentrations were higher than when the wind blows from the north. Considering the location of the incinerator, it was concluded that the plant was not a major source of PM. The data reporting the number of particles were correlated with an air quality monitoring station in Bozen centre. A good correlation was observed with parameters directly linked to vehicles traffic (benzene, toluene, CO, NOx nitride oxide and the number of vehicles) suggesting that ultra-fine particles concentrations in the urban area of Bozen depend on traffic dynamics rather than emissions from the incinerator.



Source: Ragazzi et al (2013)

Figure 3: Time trend for ultra-fine particles and NOx in the ambient air in Bozen

Conclusions

The study provided clear evidence that domestic heating and road traffic were the main sources of persistent organic air pollutants (POPs, PCDD/F is a POP). Results also confirmed previous modelling work suggesting that the Bozen plant is not a significant source of PCDD/F, or fine and ultra-fine particles. The study team suggested that further studies should be carried out to help establish the role of domestic combustion of wood as a potential contributor to PM levels.

It was also determined that ultra-fine particles concentrations in the urban area of Bozen depend on traffic rather than plant emissions.

The availability of detailed pollutant diffusion modelling (undertaken in 2001) of a long-term PCDD/F emission characterization (started in 2003) and of ultra-fine concentration values (measured in 2006–2007) have allowed the local authorities to successfully complete the proposal process for the a plant. The new plant was under construction at the time of paper publication.

6.2 Appendix 2 – Health Impact Studies

6.2.1 Dioxin emissions from a municipal solid waste incinerator and risk of invasive breast cancer: a population-based case-control study with GIS-derived exposure, 2008

Introduction and Background

It is established that risk factors for breast cancer are hormonally mediated but well-established risk factors only account for about half of all breast cancer cases. Therefore, interest has recently focused on environmental contaminants with the potential to affect breast cancer risks.

This paper was prepared by Jean-François Viel, Marie-Caroline Clément, Mathieu Hägi, Sébastien Grandjean, Bruno Challier and Arlette Danzon of the National Centre of Scientific Research, Besançon Faculty of Medicine, the Epithelial Carcinogenesis Research Team, and the Computer Medicine Department of the University Hospital of Besançon all based in France.

It is recognised that 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) is the most potent member of the dioxins family. The female population of the Seveso region in Italy where, in 1976, an industrial explosion was the cause of the highest known population exposure to TCDD is a good indicator of the hazardous potential of TCDD. 20 years after the accident, the female population residing in the area was found to be subject to a relative risk for breast cancer significantly increased by 2.1-fold.

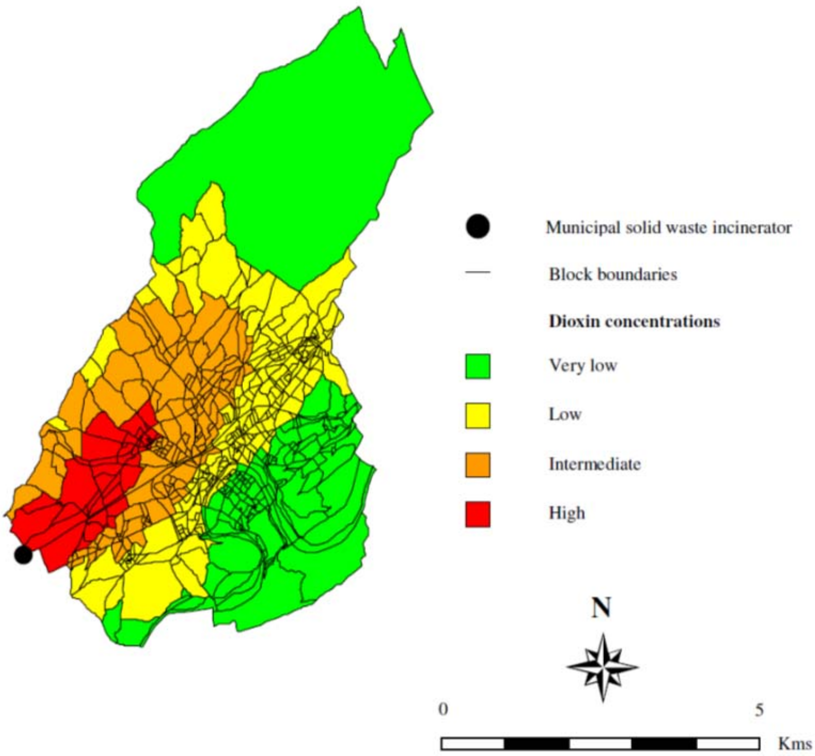
The study team detected a cluster of non-Hodgkin lymphoma (cancer of the lymphatic system) in an area containing a MSWI with high dioxin emission levels in the region of Besançon, where this study took place. The MSWI had a capacity of 7.2 metric tons per hour and was in operation since 1971. In 1998, approximately 67,000 tonnes of waste was processed by the facility. In December 1997, the first time that the dioxin concentration of the exhaust gas was ever measured, it was found to be at 16.3 ng international toxic equivalency factor (I-TEQ) m-3, whereas the European guide value is 0.1 ng I-TEQ m-3. With this in mind, it was expected that in the two decades preceding this study, considerable amounts of PCDD/Fs were released into the area surrounding the MSWI.

Method

Invasive breast cancer incidence data was extracted from the Doubs cancer registry, established in 1977 and comprehensive data source. The cancer registry contains anonymous data on age and area of residence at time of diagnosis, and histopathologic subtype. French privacy laws and confidentiality requirements limit individual and anonymous data available to researchers. Thus, sex, age categories and residence in a given block were the only data available. The block is the smallest level of geographic resolution defined for densely populated areas in the French census database.

Individual exposure was estimated through predicted ground-level air concentrations with a dispersion model (APC3 software, Aria Technologies, Colombes, France), allowing the modelling of the transport and dispersion of the MSWI's dioxin emissions. Geographic based exposure categories have been assessed through actual PCDD/F measurements from soil samples. The areas were classified in 4 different exposure categories: very low, low, intermediate and high.

A geographic information system (GIS) tools was used to attribute a dioxin concentration category to each of the 590 blocks included in the study. From respective residence block, a risk field classification for each cancer patient was obtained.



Source: Viel et al (2008)

Figure 4: Modelled dioxin concentrations at the block level, on the North-Est side of the MSWI of Besancon, France

The study compared 434 incident cases of invasive breast cancer diagnosed between 1996 and 2002, and 2,170 controls randomly selected from the 1999 population census.

Regarding other occupational or environmental sources of exposure to dioxins, there are no other local industrial sources of combustion-effluents. Highly polluting industries were replaced by small-scale advanced technologies two decades before the study took place. There were no cement kilns, iron or steel works or foundries located in the study area. Other potential thermal and combustion sources such as automobile exhausts and home heating result in diffuse emissions. This was examined to confirm that the MSWI was the single dominant source of PCDD/Fs in the urban area of Besançon.

Main Findings

The studied cases corresponded to an age-standardized (world) incidence rate of 81.4 per 100,000, to be compared to 90.4 per 100,000 for France, and to 76.9 per 100,000 for the Doubs region that comprises the city of Besançon.

The age distribution at diagnosis for all cases combined showed a bimodal pattern with incidence peaks near 50 and 70 years old. Risks models were run separately for women aged 20–59 years, and women aged 60 years or older.

Among women younger than 60 years old, no increased or decreased risk was found for any dioxin exposure category. Conversely, women over 60 years old living in the highest exposed zones were found to be 0.31 time less likely to develop invasive breast cancer than women living in the very low emission area.

The remarkable feature of the study lies in the absence of dose-response relationship but the presence of a possible threshold effect observed at the highest dioxin concentration category associated with a decreased breast cancer risk. The threshold effect was also noticeable for non-

Hodgkin lymphoma in previous studies, but with a more important risk associated with higher exposure.

The results of the study from the Besançon area stand in contrast to the findings from two previous studies:

- A mortality study conducted in Russia reported that the overall risk of breast cancer was found to be 2.1 times higher among women living in Chapaevsk. The risk was associated to intense emissions of dioxins from 1967 to 1987, by a chemical plant from this area producing hexachlorocyclohexane. The activity of the facility resulted in intense dioxin contamination in the environment (air, soil, and drinking water). High concentrations of dioxins were also detected in human milk and female workers' blood. However, the lack of methodological details for this study reduces the possibility to assess its strengths, weaknesses, and generalisability.

- Serum analysis of a subgroup of 981 women living in the high TCDD exposure zones around Seveso is also suggestive of an association between TCDD exposure and breast cancer risk. From that group, fifteen women were reported to have been diagnosed with breast cancer. However, this study also suffered some limitations such as the lack of evidence of increased incidence in the whole local population or inappropriate follow-up.

This study, on the other hand, is consistent with two hospital-based case-control studies. Both of them, independently, could not identify any association between levels of PCDD/Fs in human fat and the elevation of breast cancer risk. These studies were also limited by the small number of the population studied (79 cases and 52 controls, 22 cases and 19 controls, respectively), the hospital-based population studied (in contrast to general population-based), and others criteria.

<u>Main Conclusion</u>

The study could not identify any increased risk of breast cancer in relation to increased exposure to dioxin induced by the geographic proximity to the MSWI. The conclusion of the study suggests undertaking some residual confounding to avoid speculations about the statistical finding that women in the older category were found to be less likely to develop invasive cancer when their exposure to PCDD/Fs was very high.

Indeed, the study concludes that further investigation should consider the inconclusive evidence from studies completed so far. In order to gain new insights into the association between environmental dioxin exposure and breast cancer risk, large-scale population based studies are needed. They should include assessment of factors such as: family history, breast cancer risk factors, environmental exposures, standardized histopathology reviews and molecular characterization.

6.2.2 2012 - Long-term monitoring of dioxins and furans near a MSW incinerator: human health risks published by Waste Management & Research

Introduction and Background

Human exposure to PCDD/Fs was evaluated under different scenarios and the associated non-carcinogenic and carcinogenic risks were derived from potential exposure to the emissions of the MSWI of Tarragona (Catalonia, Spain). The study was undertaken by Lolita Vilavert, Martí Nadal, Marta Schuhmacher and José L Domingo.

Incineration has been traditionally affected by the ‘not in my back yard’ syndrome and subject to public controversy at locations where MSW incinerators are in operation. This is particularly true prior to the construction of modern facilities. Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), commonly known as dioxins, which are persistent organic pollutants (POPs). Among dioxins, 2,3,7,8-tetrachlorodibenzodioxin (TCDD) is known to cause lethal toxicity, harm reproductive capacity, be immunotoxic and cause endocrine disruptions. TCDD is classified by the International Agency for the Research of Cancer as a Group 1 agent, meaning that it is carcinogenic to humans.

To address some of these concerns, concentrations of PCDD/Fs have been uninterruptedly and periodically measured in soil and vegetation samples for 15 years (since 1996) in the Tarragona region whilst the incinerator was in operation. In addition to the air and soil sampling programme, air samples have also been collected towards the end of the monitoring period (2007-2010).

This article provides an update after the last monitoring programme was completed in May 2009, when vegetation and air samples were collected in the area surrounding the MSWI of Tarragona. 8 sampling points from 24 original sites were selected at different distances and different wind directions to be representatives of the local conditions. The choice of the location was made through a detailed study of temporal trends of PCDD/Fs from the previous programme to reject samples with high fluctuation which could be caused by specific pollution sources. Air samples were collected using a high volume active sampler. In June 2009, 8 soil and air samples were collected at the same sampling points.

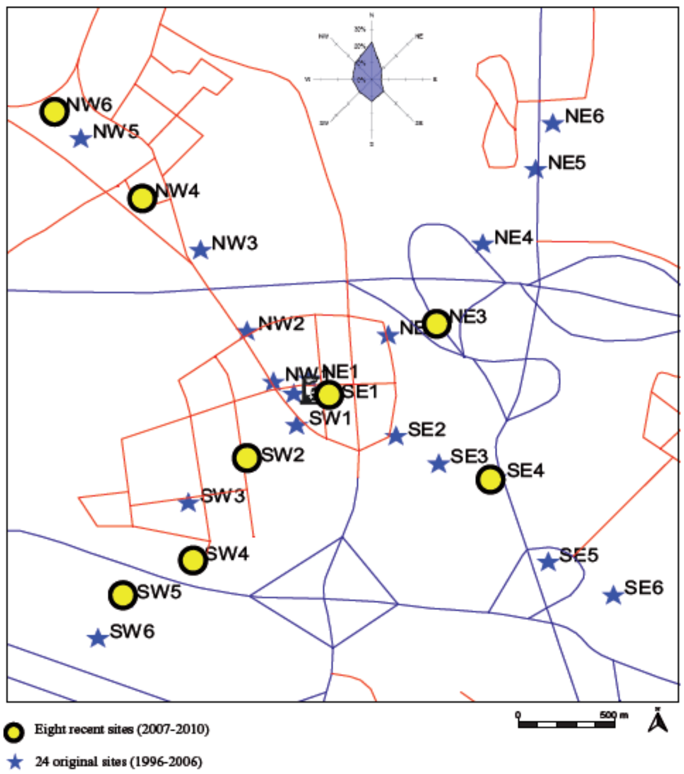


Figure 5: Original and new sampling sites and wind rose

Source: Vilavert et al (2012)

The data subsequently produced was used to evaluate the human health risks associated with the exposure to PCDD/Fs for the population living within the area potentially affected by the plant.

A human health risk assessment study was subsequently performed. Exposure was calculated considering three different pathways:

- soil ingestion,
- dermal contact,
- air inhalation.

Exposure through ingestion, dermal contact and inhalation were evaluated using equations from the US EPA methodology of human health risk assessment (US EPA, 1989).

The data was statistically analysed by using the statistical software package SPSS 17.0. This software helped determine the significance of the fluctuations observed in the concentrations measured. Values produced in 1999 were used as the baseline of the study as the first campaign of the monitoring programme in 1996 was performed before the MSWI was equipped with a new modern pollution control technology.

Main Results and Findings

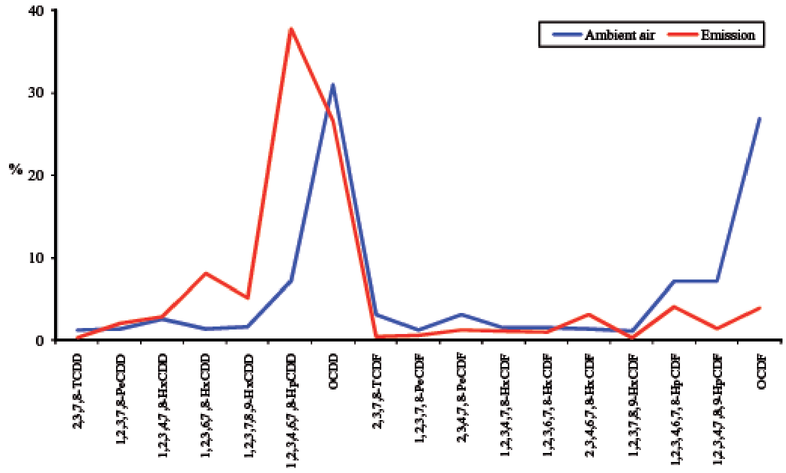
- The 2009 herbage concentrations varied between 0.04 and 0.11 ng I-TEQ kg^{-1} dry weight (dw). Between 1999 and 2009 concentrations decreased in five of the eight sampling points and increased in the remaining three points. The overall average evolution was of -45%. The concentration reported in 2010 compared to the 2007 survey decreased in seven of eight sampling points and increased in one with a global evolution of -40%.

- In 2010, the concentration in soils samples ranged from 0.11 and 1.35 ng I-TEQ kg^{-1} dw (0.13 and 1.14 ng WHO-TEQ kg^{-1} dw, respectively), with a mean of 0.58 ng WHO-TEQ kg^{-1} dw. A significant decrease of 52% was observed between the 1999 baseline and last study (2010), with important reductions in six of the eight sampling sites. In the 2008–2010 period, PCDD/Fs in soils showed a non-significant decrease of 9%.

- Air samples showed comparable levels in the different campaigns. In 2010, airborne PCDD/F levels ranged between 6.95 and 22.3 fg WHO-TEQ m^{-3}, with a mean value of 10.5 fg WHO-TEQ m^{-3}. An increase of 22% was noted with respect to the previous survey (2009), whereas a 13% reduction of PCDD/F levels was observed with respect to the first campaign (2007).

- The study also provided levels from other studies to be used as comparative references. Rovira et al. (2010) reported that PCDD/F concentrations in soils surrounding a MSWI in Mataró (Catalonia, Spain) were between 140 and 460 fg WHO-TEQ kg^{-1}, while PCDD/F levels in air samples ranged from 8 to15 fg WHO-TEQ m^{-3}. Soil samples taken in an industrial zone of Trondheim (Norway) showed levels ranging 160–14000 fg I-TEQ kg^{-1}.

- To further establish the potential influence of the MSWI on its surroundings, the ambient air PCDD/F congener profile (breakdown of the ratios for each individual PCDD/F substances in relation to the total amount of PCDD/F substances measured) was compared with that corresponding to emitted air by the MSWI. Both profiles were found to be different. On one hand, 1,2,3,4,6,7,8-HpCDD was the predominant congener in emission samples with almost 40% of the total PCDD/F emitted while it was less than 10% of the total in ambient air. On the other hand, OCDF meant < 5% of the total PCDD/F burden in the released air, but > 25% in emission samples.



Source: Vilavert et al (2012)

Figure 6: Comparison of PCDD/F congener profiles in air in 2010: Ambient air and emission gas.

Main Conclusions

Carcinogenic risk values were evaluated to be 1.85 E^{-07} and 3.66 E^{-07} for sampling points further and closer to the facility respectively. Both values are clearly below E^{-05} which is the acceptable excess of cancer risk for lifetime-exposed individuals, according to the Spanish regulation. In the UK the Health & Safety Executive believes that an individual risk of death of one in a million (E^{-06}) per annum for both workers and the public corresponds to a very low level of risk and should be used as a guideline for the boundary between the broadly acceptable and tolerable regions (HSE (2001) paragraph 130).

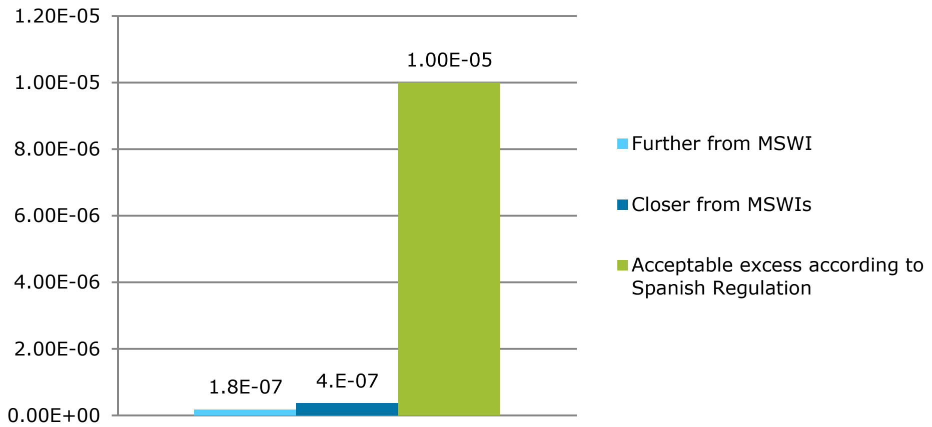


Figure 7: Carcinogenic Risk Values Relative to Distance from the MSWI and Comparison with Risk Considered Acceptable in Spanish Regulation

Although human exposure to PCDD/Fs was higher in the closest area to the MSWI, the difference was not statistically significant.

The study concluded that the environmental impact of the MSWI of Tarragona, regarding the emissions of PCDD/Fs, was low. The results of the human exposure assessment to PCDD/Fs suggested that the MSWI does not create additional health risks for the population living nearby.

6.2.3 2012 - Spatial Analysis of Health Effects of Large Industrial Incinerators in England, 1998–2008: a Study Using Matched Case–Control Areas

Background information

This study was completed by Reeve NF, Fanshawe TR, Keegan TJ from the Faculty of Health and Medicine, Lancaster University, UK 2Centre for Public Health and John Moore University.

MSWI/ERFs plants can produce emissions to air of acid gases (hydrogen chloride, hydrogen fluoride and sulphur dioxide), nitrogen oxides, trace heavy metals (cadmium, mercury, arsenic, vanadium, chromium, cobalt, copper, lead, manganese, nickel, thallium and tin), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and dioxins. Residual ash from the combustion process may contain aluminium, calcium, silicates, iron, sodium, magnesium, potassium, lead and zinc.

The International Agency for Research in Cancer classifies substances potentially carcinogenic to humans in different categories. Specifically, some of them can be released by the MSWIs: trace heavy metals and PAHs are classified as either Group 1 (carcinogenic to humans) or Group 2A (probably carcinogenic to humans) with several others classified as Group 2B (possibly carcinogenic to humans). The population residing in the vicinity of the MSWIs can be exposed to these substances through ambient air or by consumption of contaminated food. Although, there is now considerable publication reporting on studies investigating the possible risk elevation of adverse health effect in the surrounding area of industrial sources, work specific to incineration has provided mixed evidence about the effects of proximity to incinerators on health.

The objective of this study was to evaluate whether an increased risk of cancer incidence and mortality could be associated with the proximity of MSWIs in England. This study used an original approach in which circular case regions comprising an incinerator were matched to similar control regions without one, instead of using the more common method of matching individuals. The main objectives were:

1. To investigate whether there are differences in the incidences of health outcomes between case and control areas, in view of various confounding factors;
2. To explore whether incidence within the circles changes with proximity to the incinerator and
3. To set a baseline for future work allowing for prolonged lead times associated with adult carcinogenesis.

The study team carried-out a retrospective analysis of the spatial distribution of studied adverse health outcomes in the vicinity of large-scale incinerators. Health outcome counts were compared at a population level in case and in control regions. The distance from the incinerator was used as a proxy measure of exposure and the following confounding factors were taken into account: deprivation, age and sex.

The study covered the period of 1998 and 2008 and it included all MSWIs in England with a capacity in excess of 150,000 tonnes per annum commissioned on or before 31 December 1998 and for at least 5 years afterwards. This choice was based on the fact that EU Waste Incineration Directive came into application in December 2003 for new plants and exactly two years later for existing plants. Seven incinerators were selected, but two incinerators located in London were excluded because the between them was less than 20 km and, due to this circumstance, it was not possible to select suitable matching control regions.

The spatial unit used was the Lower Layer Super Output Area (LSOA) used for the UK census. Case circles included all LSOAs whose geometric centroid was included within a circle of 10 km radius around the incinerator. For each LA containing a MSWI the most similar LA, according to a set of criteria defined by the Office for National Statistics (ONS), was identified and used to define the corresponding control area. The key characteristics include: demographic structure, household composition, housing, socioeconomic character, employment and industry sector.

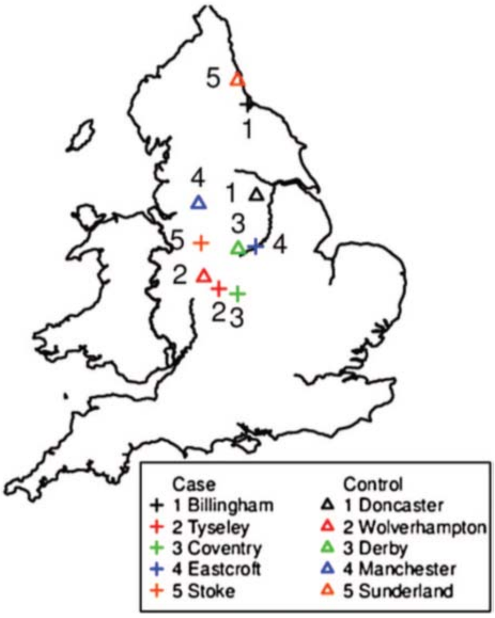


Figure 8: Location of case and control regions

Source: Maître et al (2002)

The ONS has provided annual counts at LSOA-level of the adverse health outcomes potentially linked with MSWIs by-products:

- Childhood cancer incidence (<15 years);
- Childhood leukaemia incidence (<15 years); leukaemia incidence;
- Liver cancer incidence; lung cancer incidence;
- Non-hodgkin's lymphoma incidence;
- All-cause mortality;
- Infant mortality (<1 year); and
- Liver cancer mortality.

The LSOA-level population counts were provided by 5-year age groups and sex. The English Index of Multiple Deprivation (IMD) 2004 was used a single summary indicator for seven criteria of deprivation: Income Deprivation; Employment Deprivation; Health Deprivation and Disability; Education, Skills and Training Deprivation; Barriers to Housing and Services; Crime; and Living Environment Deprivation.

Two models were used to analyse the results described in the results section: a temporal analysis and a multiplicative factor for distance.

Main results and findings

- The potential health outcome variations in relation to distance from the incinerator, and of any differences between case circles, have been analysed with the cumulative standardised mortality/ incidence ratio (SMR/SIR). It did not suggest a distance-related trend for most case circles and for most health outcomes.

- Most average unstandardised annual numbers of cases for each health outcome in both case and control circles are similar. Apparent exceptions were leukaemia incidence and infant mortality with higher average counts in case circles (329 against 289 and 260 against 202 respectively) and lung cancer incidence, which was lower in case circles (1861 against 2077).

- Most case and control temporal trends showed similar increasing patterns.

- Noticeably, each unit rise in the IMD was associated with a statistically significant increase in risk: 1.7% for infant mortality, 1.5% for lung cancer incidence and less than 1% for liver cancer incidence and mortality and all-cause mortality.

- The relative risks of residing in a case area compared with living in a control area for leukaemia incidence was 1.137. It was not found to be significant for any other health outcome except for the "all causes mortality", for which a reverse effect was detected, with a value of 0.965. There was no evidence of a distance-from-the-incinerator related variation for leukemia incidence.

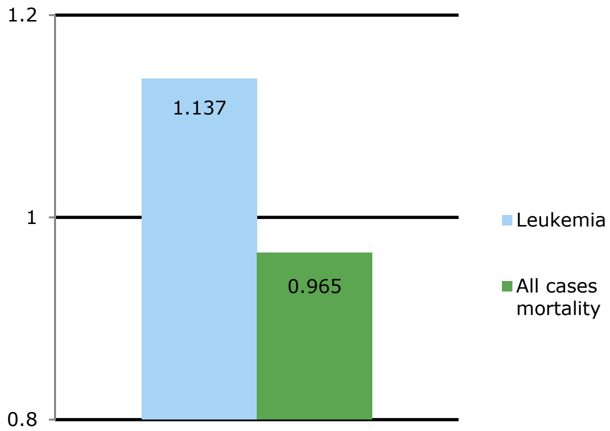


Figure 9: Relative risks of residing in a case area compared with living in a control area for Leukemia and All cases mortality incidences

Main Conclusions

The study team detected an increased risk of leukaemia incidence for individuals living in case areas, but for this health outcome, the distance did not appear to be significant and the trend, contrary to what could be anticipated, was towards a reduced risk closer to the MSWIs. A dose-response relationship with distance from the incinerator would be expected if the MSWIs were responsible for higher risks of disease and mortality. No such response could be established but it is a possibility that a distance effect was masked by other factors not taken into account such as the deprivation of the area.

Higher counts in case circles than control circles were revealed for leukaemia and infant mortality incidences. This may be an effect of the MSWIs, but it may also be at least partly explained by other contributors. It could be particularly interesting to make corrections for the age–sex structure of the regions or differences in deprivation level.

Although this study could not take into consideration all socio-economic factors, higher levels of deprivation seem heavily linked to increased incidence in the following health outcomes: all-cause and infant mortality, lung cancer incidence and liver cancer incidence and mortality.

The authors pointed-out in the conclusions that other sources of local air pollution were not considered in this study and that it would be beneficial to investigate their contribution in any future work in order to improve the significance of this analysis.

The overall conclusion is that the results of this study did not show elevated risk for the population living in areas where a MSWI was operating compared to individuals living in matched areas without any MSWI. Therefore, the findings confirm general conclusions from previous research in the field.

This study covered a large number of incinerators and it studied a wide population. However, the approach did not allow for the consideration of local factors.

6.3 Appendix 3 – Glossary of Scientific Terms

Biomonitoring
In analytical chemistry, biomonitoring is the measurement of the body burden of toxic chemical compounds, elements, or their metabolites, in biological substances. Often, these measurements are done from blood and urine samples.

COC
The Committee on the Carcinogenicity of the Chemicals in Food, Consumer Products and the Environment is an independent advisory committee that provides advice to Government departments and agencies on the potential carcinogenicity of chemicals, from natural products to new synthetic chemicals used in pesticides or pharmaceuticals.

COT
The Committee on the Toxicity of Chemicals in Food, Consumer Products and the Environment is an independent scientific committee that provides advice to the Food Standards Agency, the Department of Health and other Government Departments and Agencies on matters concerning the toxicity of chemicals.

Confounding Factors (Epidemiology)
Factors that can cause or prevent the outcome of interest, are not intermediate variables, and are not associated with the factor(s) under investigation. They give rise to situations in which the effects of two processes are not separated, or the contribution of causal factors cannot be separated, or the measure of the effect of exposure or risk is distorted because of its association with other factors influencing the outcome of the study.

Dioxins and Furans
Dioxins refer to a large group of chemicals with similar chemical structure (chlorinated dibenzo-p-dioxins and chlorinated dibenzo-p-furans). They vary greatly in toxicity, some being very toxic, others showing similar pattern to toxicity but a lower potency. TCDD is considered highly toxic in this series.

ELVs
Emissions Limit Values set for the concentration of pollutants in the legislation.

ERF
Energy Recovery Facilities are plants using technology to transform residual waste into energy: heat and / or electricity for the National Grid.

EfW
Energy from Waste facilities is a synonym of ERF.

Femtogram (fg)
One Femtogram is 1×10^{-15} gram. There are 1,000,000,000,000,000 fg in one gram.

Grey literature
Literature not produced by bodies whose sole objective is publishing or that is not indexed in a scientific database.

I-TEQ / Nm^3
International Toxic equivalency factor expresses the toxicity of dioxins, furans and PCBs in terms of the most toxic form of dioxin, 2,3,7,8-TCDD. The International Toxic Equivalent (I-TEQ) scheme by the North Atlantic Treaty Organisation (NATO) is older than Who-Teq. It was initially set up in 1989 and later extended and updated.

Microgram (µg)
One microgram is 1×10^{-6} gram. There are 1,000,000 µg in one gram.

MSW
Municipal Solid Waste

MSWI
Municipal Solid Waste Incinerator

Nanogram (ng)
One nanogram is 1 x 10 $^{-9}$ gram. There are 1,000,000,000 ng in one gram.

Non-Hodgkin lymphoma (NHL)
A type of malignant cancer of the lymphatic system or lymphoid tissue. Most lymphoma are of this type (as opposed to being Hodgkin lymphoma).

PCDD/Fs
Chlorinated dibenzo-p-dioxins and chlorinated dibenzo-p-furans, commonly called dioxins and furans.

Persistent organic pollutants (POPs)
POPs are chemical substances that persist in the environment, bioaccumulate through the food chain, and pose a risk of causing adverse effects to human health and the environment. This group of priority pollutants consists of pesticides (such as DDT), industrial chemicals (such as polychlorinated biphenyls, PCBs) and unintentional by-products of industrial processes (such as dioxins and furans).

Picogram (pg)
A picogram is 1x 10 $^{-12}$ gram. There are 1,000,000,000,000 pg in one gram.

PM_{10}, $PM_{2.5}$
The concentration (expressed in µg/m3) of particles generally less than 10 µm and 2.5 µm respectively. The terms PM10 and $PM_{2.5}$ are sometimes used to describe particles of diameter of less than 10 and 2.5 µm respectively but this is not strictly correct: the terms refer to the concentrations of particles and not to the particles themselves.

Polycyclic aromatic hydrocarbons (PAHs)
These are a group of structurally related organic compounds that contain 2 or more fused rings. They are formed as a result of combustion/pyrolysis.

Soft Tissue Sarcomas (STS)
Soft tissue sarcomas are cancers that develop from cells in the soft, supporting tissues of the body. They can occur in soft tissues such as fat, muscle, nerves, fibrous tissues, blood vessels or in any of the other tissues that support, surround and protect the organs of the body.

Tolerable Daily Intake (TDI)
An estimate of the amount of contaminant, expressed on a body weight basis (e.g. mg/kg body weight) that can be ingested daily over a lifetime without appreciable health risk.

Trace Heavy Metals
Total concentration of the following elements: As, Cd, Co, Cr, Cu, Hg, Pb, Mn, Ni, Sb, Sn, TI and V in the particulate phase expressed in ng m^{-3}).

Toxic Equivalent (TEQ)
This is a method of comparing the total relative toxicological potency within a mixture using TEFs (see above). It is calculated as the sum of the products of the concentration of each chemical multiplied by the TEF.

WHO-TEQ m^{-3}
World Health Organisation toxic equivalency factor expresses the toxicity of dioxins, furans and PCBs in terms of the most toxic form of dioxin, 2,3,7,8-TCDD.

6.4 Appendix 4 – Glossary of Emissions From Waste Combustion

- **Carbon monoxide (CO)**

Carbon monoxide is a temporary atmospheric pollutant. It is mostly emitted by internal combustion engines, but also from incomplete combustion of various other fuels including wood, coal, charcoal, oil, paraffin, propane, natural gas, and waste. The production of CO can be minimised in an EfW plant by ensuring complete waste combustion.

- **Dioxins and furans (PCDD/Fs)**

Dioxins and furans is the abbreviated or short name for a family of toxic substances that share a similar chemical structure. Most dioxins and furans are not man-made or produced intentionally, but are industry or combustion by-products. Of all of the dioxins and furans, one, 2,3,7,8-tetrachloro-p-dibenzo-dioxin (2,3,7,8 TCDD) is considered the most toxic. The productions of PCDD/Fs can be minimised by limiting favourable conditions for the formation of these compounds in furnaces and boilers. Furthermore, ERF plants usually use carbon injection systems to absorb the PCDD/Fs in combustion gases and limit their release to the atmosphere.

- **Dioxin-like Polychlorinated Biphenyls (PCBs)**

Polychlorinated biphenyls (PCBs) are not dioxins, but twelve of them have "dioxin-like" properties. Under certain conditions PCBs may form dibenzofurans through partial oxidation.

- **Fine Particulates Matter: PM_{10}, $PM_{2.5}$**

Particulate matter is a complex mixture of extremely small particles and liquid droplets. The size of particles is directly linked to their potential for causing health problems. Particles that are 10 micrometers in diameter or smaller are of concern because they generally pass through the throat and nose and enter the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects.

- **Hydrogen chloride (HCl)**

It is a colourless gas, which forms white fumes of hydrochloric acid upon contact with atmospheric humidity. The very high solubility of hydrogen chloride gas means that releases to the atmosphere are quickly washed out by rain and moisture in the air. Flue-gas cleaning systems reduce the amount of HCl released in the atmosphere; in particular, calcium oxide (lime) reacts with HCl to form $CaCl_2$.

- **Hydrogen Fluoride (HF)**

The very high solubility of hydrogen fluoride gas means that releases to the atmosphere are quickly washed out by rain and moisture in the air. Flue-gas cleaning systems reduce the amount of HF released in the atmosphere; in particular, calcium oxide (lime) reacts with HF to form CaF_2.

- **Methane (CH_4)**

At normal environmental concentrations, methane has no impacts on human health. The main impact of methane is on a global scale, as a greenhouse gas. Although levels of methane in the environment are relatively low, its "global warming potential" ranks it amongst the worst of the greenhouse gases (21 times that of CO_2).

- **Nitrogen Oxides (NOx, NO,NO_2)**

NOx refers toNOandNO_2. They are produced during combustion, especially at high temperature. Nitric oxide in the air may convert tonitric acid, which has been implicated in acid rain. Furthermore, both NO and NO_2 participate in ozone layer depletion. EfW plants usually use a De-NO_x systems to minimise the release of NO_x.

- **Polycyclic aromatic hydrocarbon (PAHs)**

PAHs are hydrocarbons—organic compounds containing only carbon and hydrogen molecules. The toxicity of PAHs is structure-dependent. PAHs forms, with the same formula, can vary from being nontoxic to extremely toxic. The US EPA has classified seven PAH compounds as probable human carcinogens: benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

- **Sulphur dioxide (SO_2)**

Sulphur dioxide is the product of the burning sulphur or burning materials that contain sulphur. Sulphur dioxide emissions are a precursor toacid rain and atmospheric particulates. Flue-gas cleaning systems reduce the amount of SO_2 released in the atmosphere; in particular, calcium oxide (lime) reacts with sulphur dioxide to form calcium sulphite.

- **Tetrachloroethene** (C_2Cl_4)

Tetrachloroethene is a common soil contaminant. With a specific gravity greater than 1, tetrachloroethene will be present as a dense non-aqueous phase liquid (DNAPL) if sufficient quantities are released. The International Agency for Research on Cancer has classified tetrachloroethene as a Group 2A carcinogen, which means that it is probably carcinogenic to humans.

- **Trace Heavy Metals: Cadmium (Cd), Nickel (Ni), Arsenic (As), Mercury (Hg), Chromium (Cr)**

Some metals are naturally found in the body and are necessary for proper human health. Iron can help to prevent anemia, and zinc is a cofactor in over 100 enzyme reactions. All though trace metals are good for humans, in high doses they may be toxic to the body.

- **Volatile organic compounds (VOCs)**

VOCs are often compounds of fuels, solvents, hydraulic fluids, paint thinners, and dry-cleaning agents commonly used in urban settings. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects. Some organics are suspected or known to cause cancer in humans.

6.5 Appendix 5 – Literature Review Matrix

Peer reviewed publications	Name	Review of Environmental and Health Effects of Waste Management	The Impact on Health of Emissions to Air from Municipal Waste Incinerators	Review of International Best Practices of Environmental Surveillance for Energy-From-Waste Facilities	Update Statement on the Review of Cancer Incidence near Municipal Solid Waste Incinerators	Systematic review of epidemiological studies on health effects associated with management of solid waste
	Publication date	2004	2009	2008	2000 & 2009	2009
	Organisation / Consultant	Enviros, University of Birmingham and Defra	Health Protection Agency	Jacques Whitford	Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment	Dep. Epidemiology, Reg. Health Service Lazio (Italy) & Div. Epidemiology, Public Health and Primary Care, Imperial College (UK)
A Burning Questions: Incineration of Wastes and Implications for Human Health, (Research Report No.8) (1992); Gatrell, A. C. and Lovett, A. North West Regional Research Laboratory, Lancaster University, Lancaster, UK.		X				
Adverse Pregnancy Outcomes around Incinerators and Crematoriums in Cumbria, north west England, 1956-93 (2003); Dummer, T, Dickinson, H, and Parker, L. J Epidemiol Community Health. 57, 456-461.		X				X
An evaluation of the occupational health risks to workers in a hazardous waste incinerator (2004); Bakoglu, M., Karademir, A., & Ayberk, S. Journal of Occupational Health				X		
Arsenic burden survey among refuse incinerator workers (2005); Chao, C. L. & Hwang, K. C. Journal of Postgraduate Medicine				X		
Biomonitoring of PCDD/Fs in populations living near portuguese solid waste incinerators: levels in human milk (2007b); Reis, M. F., Sampaio, C., Aguiar, P., Mauricio, M. J., Pereira, M. J., & Papke, O. Chemosphere				X		
Biomonitoring study of people living near or working at a municipal waste incinerator (2000); Gonzalez, C. A., Kogevinas, M., Gadea, E., Huici, A., Bosch, A., Bleda, M. J. and Papke, O. Archive of Environmental Health.		X				
Cancer incidence near municipal solid waste incinerators in Great Britain (1996); P. Elliott, G. Shaddick, I. Kleinschmidt, D. Jolley, P. Walls, J. Beresford and C. Grundy British Journal of Cancer.		X	X		X	X

Peer reviewed publications	Name Publication date Organisation / Consultant	Review of Environmental and Health Effects of Waste Management 2004 Enviros, University of Birmingham and Defra	The Impact on Health of Emissions to Air from Municipal Waste Incinerators 2009 Health Protection Agency	Review of International Best Practices of Environmental Surveillance for Energy-From-Waste Facilities 2008 Jacques Whitford	Update Statement on the Review of Cancer Incidence near Municipal Solid Waste Incinerators 2000 & 2009 Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment	Systematic review of epidemiological studies on health effects associated with management of solid waste 2009 Dep. Epidemiology, Reg. Health Service Lazio (Italy) & Div. Epidemiology, Public Health and Primary Care, Imperial College (UK)
Cancer Incidence Near Municipal Solid Waste Incinerators in Great Britain 2000; Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment		X	X			
Cancer incidence near municipal solid waste incinerators in Great Britain. Part 2: histopathological and case-note review of primary liver cancer cases (2000); P Elliott, N Eaton, G Shaddick and R Carter Bristish Journal of Cancer.		X			X	X
Cancer risk assessment for the inhalation of metals from municipal solid waste incinerators impacting Chicago (1993) Hallenbeck, W, Breen, S, and Brenniman Bulletin of Environmental Contamination & Toxicology		X				
Childhood cancers, birthplaces, incinerators and landfill sites (2000); Knox, E. International Journal of Epidemiology		X			X	X
Comparison of respiratory symptoms among community residents near waste disposal incinerators (2000); Mohan, A. K., Degnan, D., Feigley, C. E., Shy, C. M., Hornung, C. A., Mustafa, T. and Macera, C. A. International Journal of Environmental Health Research.		X				
Determinants of dioxins and furans in blood of non-occupationally exposed populations living near Portuguese solid waste incinerators (2007a); Reis, M. F., Miguel, J. P., Sampaio, C., Aguiar, P., Melim, J. M., & Papke, O. Chemosphere				X		
Dioxin accumulation in residents around incinerators (2003); Fierens, S., Mairesse, H., Hermans, C., Bernard, A., Eppe, G., Focant, J. F. et al. Journal of Toxicology and Environmental Health				X		

Peer reviewed publications	Name	Review of Environmental and Health Effects of Waste Management	The Impact on Health of Emissions to Air from Municipal Waste Incinerators	Review of International Best Practices of Environmental Surveillance for Energy-From-Waste Facilities	Update Statement on the Review of Cancer Incidence near Municipal Solid Waste Incinerators	Systematic review of epidemiological studies on health effects associated with management of solid waste
	Publication date	2004	2009	2008	2000 & 2009	2009
	Organisation / Consultant	Enviros, University of Birmingham and Defra	Health Protection Agency	Jacques Whitford	Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment	Dep. Epidemiology, Reg. Health Service Lazio (Italy) & Div. Epidemiology, Public Health and Primary Care, Imperial College (UK)
Dioxin emissions from a municipal solid waste incinerator and risk of invasive breast cancer: a population-based case-control study with GIS-derived exposure (2008); J-F. Viel, M-C. Clément, M. Hägi, S. Grandjean, B. Challier and A. Danzon International Journal of Health Geographics			X		X	X
Dioxin emissions from a solid waste incinerator and risk of non-Hodgkin lymphoma (2003); J-F Viel, M-C Clément, M Hägi, S Grandjean, B Challier and A Danzon International Journal of Health Geographics		X	X		X	
Dioxin from Swedish municipal incinerators and the occurrence of cleft lip and palate malformations (1989); Jansson, B. and Voog, L. International Journal of Environmental Studies		X				X
Do waste incinerators induce adverse respiratory effects? An air quality and epidemiological study of six communities (1995); Shy CM, Degnan D, Fox DL, Mukerjee S, Hazucha MJ, Boehlecke BA, Rothenbacher D, Briggs PM, Devlin RB, Wallace DD, Stevens RK, Bromberg PA. Environmental Health Perspectives.						X
Do waste incinerators induce adverse respiratory effects? An air quality and epidemiological study of six communities (1995);Shy CM, Degnan D, Fox DL, Mukerjee S, Hazucha MJ, Boehlecke BA, Rothenbacher D, Briggs PM, Devlin RB, Wallace DD, Stevens RK, Bromberg PA Environmental Health Perspectives		X				
Evaluating the environmental impact of an old municipal waste incinerator: PCDD/F levels in soil and vegetation samples (2001); Domingo J. et al. Journal of Hazardous Materials 76(1)		X				

Peer reviewed publications	Name Publication date Organisation / Consultant	Review of Environmental and Health Effects of Waste Management 2004 Enviros, University of Birmingham and Defra	The Impact on Health of Emissions to Air from Municipal Waste Incinerators 2009 Health Protection Agency	Review of International Best Practices of Environmental Surveillance for Energy-From-Waste Facilities 2008 Jacques Whitford	Update Statement on the Review of Cancer Incidence near Municipal Solid Waste Incinerators 2000 & 2009 Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment	Systematic review of epidemiological studies on health effects associated with management of solid waste 2009 Dep. Epidemiology, Reg. Health Service Lazio (Italy) & Div. Epidemiology, Public Health and Primary Care, Imperial College (UK)
Exposure assessment of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) in temporary municipal-waste-incinerator maintenance workers before and after annual maintenance (2006); Shih, T. S., Chen, H. L., Wu, Y. L., Lin, Y. C., & Lee, C. C. Chemosphere				X		
Health and environmental effects of landfilling and incineration of waste a literature review (2003); Publiched by Eire Health Research Board		X				
Health effects of exposure to waste incinerator emissions: a review of epidemiological studies (2004); Franchini M, Rial M, Buiatti E, Bianchi F. Annali dellIstituto Superiore di Sanita.						X
Health effects of waste combustion products (1997); Institute for Environment and Health.		X				
Health effects of waste incineration: A review of epidemiologic studies (2001); Hu, S. W. and Shy, C. M. Journal of the Air & Waste Management Association. 51(7), 1100-1109.		X				X
Health risk assessment of dioxin emissions from municipal waste incinerators: The Neerlandquarter (Wilrijk, Belgium) (2001); Nouwen J. et al. Chemosphere		X				
Human exposure to heavy metals in the vicinity of Portuguese solid waste incinerators--Part 1: biomonitoring of Pb, Cd and Hg in blood of the general population (2007c); Reis, M. F., Sampaio, C., Brantes, A., Aniceto, P., Melim, M., Cardoso, L. et al. International Journal of Hygiene and Environmental Health				X		

Peer reviewed publications	Name Publication date Organisation / Consultant	Review of Environmental and Health Effects of Waste Management 2004 Enviros, University of Birmingham and Defra	The Impact on Health of Emissions to Air from Municipal Waste Incinerators 2009 Health Protection Agency	Review of International Best Practices of Environmental Surveillance for Energy-From-Waste Facilities 2008 Jacques Whitford	Update Statement on the Review of Cancer Incidence near Municipal Solid Waste Incinerators 2000 & 2009 Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment	Systematic review of epidemiological studies on health effects associated with management of solid waste 2009 Dep. Epidemiology, Reg. Health Service Lazio (Italy) & Div. Epidemiology, Public Health and Primary Care, Imperial College (UK)
Human exposure to heavy metals in the vicinity of Portuguese solid waste incinerators--Part 2: biomonitoring of lead in maternal and umbilical cord blood. (2007e); Reis, M. F., Sampaio, C., Brantes, A., Aniceto, P., Melim, M., Cardoso, L. et al. International Journal of Hygiene and Environmental Health				X		
Human exposure to heavy metals in the vicinity of Portuguese solid waste incinerators--Part 3: biomonitoring of Pb in blood of children under the age of 6 years(2007d); Reis, M. F., Sampaio, C., Brantes, A., Aniceto, P., Melim, M., Cardoso, L. et al. International Journal of Hygiene and Environmental Health				X		
Incidence of cancer among persons living near a municipal solid waste landfill site in Montreal, Quebec (1995); Goldberg, M. S., al-Homsi, N., Goulet, L. and Riberdy, H. Archive of Environmental Health.		X				
Incineration and Human Health, State of Knowledge of the Impact of Waste Incinerators on Human Health, (2001); Allsopp, M., Costner, P. and Johnston, P. Greenpeace Research Laboratories, University of Exeter.		X				
Incinerator toxic emissions: a brief summary of human health effects with a note on regulatory control (2000); Rowat S. Medical Hypotheses		X				
Morbidity among municipal waste incinerator workers (1992); Bresnitz EA, Roseman J, Becker D, Gracely E. American Journal of Industrial Medicine.						X
Morbidity among municipal waste incinerator workers: a cross-sectional study (2003); Hours M, Anzivino-Viricel L, Maitre A, Perdrix A, Perrodin Y, Charbotel B, Bergeret A. International Archives of Occupational and Environmental Health.						X

Peer reviewed publications	Name Publication date Organisation / Consultant	Review of Environmental and Health Effects of Waste Management 2004 Enviros, University of Birmingham and Defra	The Impact on Health of Emissions to Air from Municipal Waste Incinerators 2009 Health Protection Agency	Review of International Best Practices of Environmental Surveillance for Energy-From-Waste Facilities 2008 Jacques Whitford	Update Statement on the Review of Cancer Incidence near Municipal Solid Waste Incinerators 2000 & 2009 Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment	Systematic review of epidemiological studies on health effects associated with management of solid waste 2009 Dep. Epidemiology, Reg. Health Service Lazio (Italy) & Div. Epidemiology, Public Health and Primary Care, Imperial College (UK)
Mortality among workers at municipal waste incinerators in Rome: a retrospective cohort study (1997); Rapiti E, Sperati A, Fano V, Dell'Orco V, Forastiere F. American Journal of Industrial Medicine.						X
Mortality for non-Hodgkin lymphoma and soft-tissue sarcoma in the surrounding area of an urban waste incinerator. Campi Bisenzio (Tuscany, Italy) 1981-2001 (2005). Biggeri A, Catelan D. Epidemiologia & Prevenzione.						X
Mortality for non-Hodgkin lymphoma in the period 1981-2000 in 25 Italian municipalities with urban solid waste incinerators (2006); Bianchi F, Minichilli F. Epidemiologia & Prevenzione						X
Municipal solid waste incineration: health effects, regulation and public communication (2001); Farmer, A., and Hjerp, P., National Society for Clean Air.		X				
Overview of Waste Management Options: Their Efficacy and Acceptability. In. Environmental and Health Impact of Solid Waste Management Activities. Issues in Environmental Science and Technology 18, Eds: R. E. Hester and R. M. Harrison. Cambridge, Royal Society of Chemistry		X				
Polybrominated diphenyl ethers in blood from Korean incinerator workers and general population. (2007); Lee, S. J., Ikonomou, M. G., Park, H., Baek, S. Y., & Chang, Y. S. Chemosphere				X		
Polychlorinated dibenzo-p-dioxin and dibenzofuran concentrations in serum samples of workers at intermittently burning municipal waste incinerators in Japan (2002); Kumagai, S., Koda, S., Miyakita, T., & Ueno, M. Occupational and Environmental Medicine				X		

Peer reviewed publications	Name Publication date Organisation / Consultant	Review of Environmental and Health Effects of Waste Management 2004 Enviros, University of Birmingham and Defra	The Impact on Health of Emissions to Air from Municipal Waste Incinerators 2009 Health Protection Agency	Review of International Best Practices of Environmental Surveillance for Energy-From-Waste Facilities 2008 Jacques Whitford	Update Statement on the Review of Cancer Incidence near Municipal Solid Waste Incinerators 2000 & 2009 Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment	Systematic review of epidemiological studies on health effects associated with management of solid waste 2009 Dep. Epidemiology, Reg. Health Service Lazio (Italy) & Div. Epidemiology, Public Health and Primary Care, Imperial College (UK)
Polychlorinated dibenzo-p-dioxin and dibenzofuran concentrations in the serum samples of workers at continuously burning municipal waste incinerators in Japan (2000); Kumagai, S., Koda, S., Miyakita, T., Yamaguchi, H., Katagi, K., & Yasuda, N. Occupational and Environmental Medicine,				X		
Relationship between distance of schools from the nearest municipal waste incineration plant and child health in Japan (2005); Miyake Y, Yura A, Misaki H, Ikeda Y, Usui T, Iki M, Shimizu T. European Journal of Epidemiology.						X
Review of Environmental and Health Effects of Waste Management (2004); Enviros, University of Birmingham and Defra					X	X
Review of Environmental and Health Effects of Waste Management (2004); Enviros, University of Birmingham and Defra			X		X	
Risk factors affecting blood PCDDs and PCDFs in residents living near an industrial incinerator in Korea (2006); Leem, J. H., Lee, D. S., & Kim, J. Archives of Environmental Contamination and Toxicology				X		
Risk for non Hodgkin's lymphoma in the vicinity of French municipal solid waste incinerators (2008); J.-F. Viel, C. Daniau, S. Goria, Pascal Fabre, P. de Crouy-Chanel, E.-A. Sauleau and P. Empereur-Bissonnet Environmental Health.			X		X	X
Risk of adverse reproductive outcomes associated with proximity to municipal solid waste incinerators with high dioxin emission levels in Japan (2004); Tango T, Fujita T, Tanihata T, Minowa M, Doi Y, Kato N, Kunikane S, Uchiyama I, Tanaka M, Uehata T. Journal of Epidemiology & Community Health.						X

Peer reviewed publications	Name Publication date Organisation / Consultant	Review of Environmental and Health Effects of Waste Management 2004 Enviros, University of Birmingham and Defra	The Impact on Health of Emissions to Air from Municipal Waste Incinerators 2009 Health Protection Agency	Review of International Best Practices of Environmental Surveillance for Energy-From-Waste Facilities 2008 Jacques Whitford	Update Statement on the Review of Cancer Incidence near Municipal Solid Waste Incinerators 2000 & 2009 Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment	Systematic review of epidemiological studies on health effects associated with management of solid waste 2009 Dep. Epidemiology, Reg. Health Service Lazio (Italy) & Div. Epidemiology, Public Health and Primary Care, Imperial College (UK)
Risk of congenital anomalies in the vicinity of municipal solid waste incinerators (2004); Cordier S, Chevrier C, Robert-Gnansia E, Lorente C, Brula P, Hours M Occupational and Environmental Medicine.						X
Risk of soft tissue sarcomas and residence in the neighbourhood of an incinerator of industrial wastes (2003); P Comba, V Ascoli, S Belli, M Benedetti, L Gatti, P Ricci, A Tieghi Occup Env Medicine			X		X	X
Sarcoma risk and dioxin emissions from incinerators and industrial plants: a population-based case-control study (Italy) (2007); P Zambon, P Ricci, E Bovo, A Casula, M Gattolin, A Rita Fiore, F Chiosi and S Guzzinati Environmental Health			X		X	X
Serum levels of PCDDs, PCDFs and PCBs in non-occupationally exposed population groups living near two incineration plants in Tuscany, Italy (2008); De Felip E., Abballe, A., Casalino, F., di, D. A., Domenici, P., Iacovella, N. et al.. Chemosphere				X		
Serum PCDD/F concentration distribution in residents living in the vicinity of an incinerator and its association with predicted ambient dioxin exposure (2004); Chen, H. L., Su, H. J., Liao, P. C., Chen, C. H., & Lee, C. C. Chemosphere				X		
Soft-Tissue Sarcoma and Non-Hodgkin's Lymphoma Clusters around a Municipal Solid Waste Incinerator with High Dioxin Emission Levels (2000) J_F Viel, P Arveux, J Baverel and J-Y Cahn American Journal of Epidemiology		X	X		X	X
Survey on the health effects of chronic exposure to dioxins and its accumulation on workers of a municipal solid waste incinerator, rural part of Osaka Prefecture, and the results of extended survey afterwards (2003); Takata T. Industrial Health						X

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The French dioxin and incinerators study France (2008); Frery, N., Volatier, JL., Zeghnoun, A., Sarter, H., Falq, G., Thebault, A. et al. French Institute for Public Health Surveillance (inVS).				X		
The Health Effects of Waste (2005); British Society of Ecological Medicine					X	
The Portugese experience on environmental health surveillance related to USW incineration. (2007); Reis, M. F. In Workshop on "urban solid waste incinerator plants: technical aspects and health impacts".				X		
Update Statement on the Review of Cancer Incidence near Municipal Solid Waste Incinerators (2009); Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment			X			
Waste Incineration and Public Health (2000); National Research Council (NRC)				X		
Williams, F. L., Lawson, A. B. and Lloyd, O. L. (1992). Low sex ratios of births in areas at risk from air pollution from incinerators, as shown by geographical analysis and 3-dimensional mapping, International Journal of Epidemiology		X				X