Energy from Waste Facility in the Region of Durham

Prepared for:

The Medical Officer of Health
Durham Region

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Note to the Reader

This report was commissioned by Dr. Robert Kyle, Commissioner and Medical Officer of Health, Regional Municipality of Durham, on June 28, 2007. There is a Précis which provides directly answers to the questions posed by the Medical Officer of Health. The Report Executive Summary contains the essential points of each Section in summary form with some supporting detail. It is a reasonable substitute for the whole report. The text of the report is supported by more details in five appendices.

The author was a reviewer for the Durham EFW Generic Risk Assessment carried out by Jacques Whitford Ltd. Payment for both projects is from the Regional Municipality of Durham. The author declares no interest in any of the participating consulting companies or in the development of any energy from waste facility and therefore does not have any conflict of interest with the current assignment.

Any omissions or errors are the responsibility of the author.

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Précis

The Halton 4A Report concluded that EFW facilities using currently available modern (thermal) methods and pollution control technology are not expected to pose a significant risk to the public. It identified potential health concerns. In addition, the Halton 4A Report stated that any new facility should be subject to a site specific risk assessment to identify local issues and ensure that it will not pose a risk to the public.

This author (Dr. Smith) concludes that the current epidemiologic literature (2000-2007) is inconclusive and does not demonstrate one way or another that modern incinerators have associated health effects on the people living around them. This conclusion is not materially different from the inferences made in the Halton 4A Report review of the health effects of incineration.

On the whole, the incinerator-generated contaminant load as measured in blood of residents living near-by is similar to the same contaminant load in other populations. Possibly this could be because sources other than incinerators generally provide a higher proportion of the total burden of exposure for these contaminants. The "incinerator literature" alone cannot be used to support or dismiss possible health effects from the measured levels of some of the contaminants in people living around incinerators.

The epidemiologic method in general is limited in that it can only indicate statistical associations between exposure and disease, not a cause and effect relationship. A cause and effect relationship can be inferred after careful analysis of all studies and applying appropriate criteria.

The generic risk assessment for an EFW facility in Durham Region (Jacques Whitford Report) is properly carried out. The methods used were clearly explained and therefore, the entire exercise can be duplicated by other investigators. As expected, it erred on the side of health protection or "conservatism" despite its failure to assess upset conditions, a scenario which should be applied to any site specific risk assessment if situations with upset conditions are relevant to the EFW facility chosen for Durham Region. Ultrafine particulate and nanoparticle exposure were not considered as there are currently no risk assessment methods to do so nor measurement technology in place to monitor.

It should be noted that these ultrafine and nanoparticles are emissions of concern from hazardous waste incineration, as opposed to municipal EFW facilities. [1] Dioxins are produced de novo from incineration regardless of what is burned. Plastics are destroyed completely by combustion and any recombination into polychlorinated aromatic compounds that occurs in the burning process is dealt with in the emissions control technology. The inference that plastics per se are a source of nanoparticles is incorrect. Limiting plastics in general is not a prerequisite of the incineration technology.

With respect to the risk assessment process *per se*, it is the only procedure that can produce quantitative estimates of predicted health effects. The methods for conducting a human health risk assessment are reproducible and subject to quantitative checks.

Epidemiology, risk assessment and biological monitoring methods assist regulatory bodies, support public health activities, and bring a greater understanding of the interaction of humans with their environment. Because each method can have limits and challenges, a combination best serves public health.

Environmental quality oversight and health surveillance activities constitute engagement of communities with public health agencies (health, environment) and the industry and may be considered part of a responsible program for environmental quality assurance.

Community surveillance can take the form of environmental monitoring and reporting, timely responses to health concerns, and continued engagement with communities throughout the life of the facility. Health studies in communities have a role, but these studies should be considered carefully with respect to objectives and methodology before undertaking them.

[1] Cormier SA, Lomnicki S, Backes W, Dellinger B, 2006. Origin and health impacts of emissions of toxic by-products and fine particles from combustion and thermal treatment of hazardous wastes and materials. Environmental Health Perspectives. Jun; 114(6):810-7.

Energy from Waste Facility in the Region of Durham

Executive Summary

This work was undertaken at the request of the Medical Officer of Health of Durham Region. Durham Region is currently undergoing a process of choosing a site for an energy-from-waste (EFW) facility within its boundaries. As part of the process of public consultation before the selection of a contractor and a specific technology, a generic risk assessment was carried out for the Region by Jacques Whitford[2]. In the course of public consultation, a number of issues arose regarding the integrity of the generic risk assessment which is of a "model" hypothetical facility. The issue of health effects from EFW facilities, formerly called "incinerators", also came under scrutiny from the review of a report of an assessment of health effects of incineration provided to a nearby jurisdiction (Halton Region). The process and conclusions of the health effects assessment including the assessment of the literature on incineration and health became issues of concern.

The Regional Municipality of Durham had undergone a process of selection which indicated that EFW as their preferred residual waste management option – that is after recycling and composting are optimized. The Region is now undertaking consultation in preparation for the selection of a provider and a technology for the chosen method to handle residual waste.

The Health Department will contribute important information to Council about the public health impacts of the introduction of such a facility into the Region. In order to evaluate current information and gather new information, the Medical Officer of Health requested an assessment of the literature of incineration-related health effects and of the reports from a neighboring health department which generated considerable public concern.

[2] Jacques Whitford. Energy From Waste Generic Risk Assessment Feasibility Study. June 14, 2007 Report # 1009497.02

Four objectives are the focus of this report as outlined in correspondence with the Durham Region Medical Officer of Health:

A. Provide advice on Section 4a & b (pages 12-15) of the Halton 4A Report[3] (the health assessment, literature search and conclusions arising)

1. What do environmental epidemiology studies of incinerators generally have to say and the pitfalls inherent in these types of studies?

B. Soundness of the Durham generic risk assessment report

1. Is there any missing information that needs to be reviewed that may have bearing on either the generic or site specific Human Health Risk Assessment (HHRA) that will be conducted? (Bioaccumulation of dioxins and furans, *etc*; greenhouse gas emissions, regulatory air quality guidelines / standards, ultra fine particles, *etc*.)

C. An independent comment on risk assessment in general and to what extent does the draft generic HHRA conform to the basic tenets of risk assessment.

D. What are best practices for establishing an environmental monitoring program?

This report addresses these questions in sequence.

The Halton Report Step 4A - Chapter 5 Health Concerns Related to EFW Systems ("Halton 4A") examines the peer reviewed epidemiologic literature and grey literature relating incineration and health effects. The authors considered original research, research reviews and governmental reports. The Halton 4A report identifies chemicals of concern. With respect to health effects in communities around incinerators, the Halton 4A authors conclude that there are potential *health concerns* with incineration but the literature they cited generally involves old incinerators which have higher emissions than retrofitted or new incinerators. The Halton 4a Report agrees with the conclusions of the DEFRA 2004 (governmental) Report and with the conclusions of other review publications that state that **EFW facilities using currently available modern (thermal) methods and pollution control technology are not expected to pose a significant risk to the public. In addition, the Halton 4A Report states that any new facility should be subject to a site specific risk assessment to identify local issues and ensure that it will not pose a risk to the public.**

This author (Dr. Smith) reviewed the current epidemiologic literature on incineration and health of communities around them. A number of new research publications were added to the body of literature considered in the Halton 4AReport. Some 17 publications were

[3] Regional Municipality of Halton, Step 4A: Identification and Description of Potential Health and Environmental Effects. 30 May 2007. (Consulting Report done under contract to Genivar, Ramboll, Jacques Whitford, Deloitte, URS).

assessed for validity in developing an opinion about incineration and health effects, including several studies that had not been considered in the Halton 4A report. **This author concludes that the current epidemiologic literature on health effects of incinerators on local communities (2000-2007) is inconclusive and does not demonstrate one way or another that modern incinerators have associated health effects on the people living around them.**

Some important new information provided greater insight into the assessment of health impacts of the new generation of incinerators. The direct testing for contaminants (biomonitoring) of people living around modern or upgraded incinerators provides a reasonably good baseline estimate of contaminant load. Such testing does not demonstrate an increased load of key contaminants emitted from incinerators. The literature does not provide any insight into the proportion of the contaminant load in people that is attributable to emissions from current modern technology incinerators.

On the whole, the incinerator-generated contaminant load as measured in blood of residents living near-by is similar to the same contaminant load in other populations. Two possible explanations are considered: 1) emissions from incinerators are considered very small for dioxins, furans, and heavy metals; and 2) sources other than incinerators generally provide a higher proportion of the total burden of exposure for these contaminants than incinerators.

The "incinerator literature" alone cannot be used to support or dismiss possible health effects from the measured load of some of the contaminants in people living around incinerators.

There are inherent pitfalls in the epidemiologic method applied to environmental settings especially because it is necessarily observational, that is, exposures are not under the control of the researcher, so that most studies have proxy or indirect measures of exposure. If a single well conducted environmental epidemiology study finds an association, this does not necessarily invoke a causal relationship between an exposure and a health effect.

Making causal links with epidemiology as the tool requires many studies examining a relationship from different perspectives. It is not the number of studies that counts, but rather the methodology and how well they are conducted, what information can be derived from them with relative certainty, and what the weight is of all of the evidence for all studies together. A systematic review of the literature provides a summary of all of the evidence. The net results of a systematic review must then be viewed with yet another lens, - application of criteria that consider consistency of associations that make sense. There are various sets of criteria used for that process, but the most commonly used for inferring causality in occupational and environmental settings are the criteria of

Bradford Hill[4,5] elaborated in Section 6. **In summary, the epidemiologic method is limited in that it can only indicate statistical associations between an exposure and an outcome and not a causal relationship. Causality can be inferred after careful systematic analysis of all studies and applying appropriate criteria.**

The generic risk assessment for the Durham EFW facility carried out by Jacques Whitford Ltd., used accepted standard methodologies, standard air dispersion and deposition models of incinerator emissions, and calculations of risk measured against current regulatory emissions standards in Ontario or health benchmarks from the literature. The study infers acceptability of risk if the net results are at or below the benchmark regulatory risk of 1 in a million for cancer, and a hazard quotient under one for non cancer health effects. However, the exposure assumptions made were extreme, and provided a conservative estimate of risks, that is, highly protective of health. As one example, the community exposure to dioxins and furans is assumed to occur for the lifetime of the person living in the area and at the concentrations in the environment at the level theoretically attained after 35 years of facility operations. The report makes assumptions of susceptibility by using the health benchmarks applicable to the most vulnerable in the community in the different scenarios. The generic risk assessment did not make calculations of risk during upset conditions. Modern incinerators are unlikely to experience these so called upset events because the system is shut off if there is a malfunction. Hence, this scenario was not considered relevant. In addition, exposures during upset conditions would tend to be very short term whereas the regulations frame risks on long term exposure to carcinogens and non-carcinogens.

The generic risk assessment of the model community is limited, as are all risk assessments, in that it did not make calculations for complex mixture exposures, unless such mixtures are already regulated as such (*i.e.*, PAHs, dioxins and furans). It did not consider particulate exposure unless the particulate is characterized and regulated (i.e., PM_{10} and $PM_{2.5}$). Hence the issue of "nanoparticles" exposure was not and could not be addressed as a regulated toxic exposure; there are no specific risk assessment techniques or sufficient toxicological information available currently to do so. Therefore this is not a failing of the risk assessment methods used or of this report *per se*.[6,7] The report does not address upset conditions and any future risk assessment should do so if such scenario applies to the technology and operations used.

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[4] Hill AB. (1965). The environment and disease: association or causation? *Proceedings of the Royal Society of Medicine*, 58, 295-300.

[5] The Bradford Hill criteria include strength and direction of an association, dose response, temporal sequence, consistency, theoretical plausibility, biologic coherence, specificity of effect, analogy and experiment.

[6] Grahame T, Schlesinger RB. Health Effects of Airborne Particulate Matter: Do we know enough to consider regulating specific particle types or sources? Inhalation Toxicology 2007;19(6):457-481.

[7] Westheit DB, Borm OA, Hennes, C, Lademann J. 2007. Testing strategies to establish the safety of nanomaterials. Conclusions of an ECETOC Workshop. Inhalation Toxicology. 19(8):631-643.

In summary, the generic risk assessment is properly carried out. The methods used were clearly explained and therefore, the entire exercise can be duplicated by other investigators. As expected, it erred on the side of health protection or "conservatism" despite its failure to assess upset conditions, a scenario which should be applied to any site specific risk assessment of EFW facility chosen for Durham Region in the future, if situations with upset conditions are relevant.

The risk assessment process can calculate health risk during regular and upset conditions, considers pathways of exposure so that interventions can occur, and can put boundaries on actions that lessen exposures to residents around the facility. **The methods for conducting a human health risk assessment are reproducible and subject to quantitative checks. With respect to the risk assessment process *per se*, it is the only procedure that can produce quantitative estimates of predicted health effects.**

Epidemiology is a complimentary method to risk assessment in managing environmental risks. Greater precision can be achieved in calculating exposure from environmental contaminants and health effects by using the risk assessment methodology coupled by information from epidemiology, and from direct measurement of exposures (biomonitoring). Biomonitoring is very useful in measuring total exposure (from all sources) and in relating these measures of exposure to health conditions in well executed and controlled epidemiological studies. **Epidemiology, risk assessment and biological monitoring methods assist regulatory bodies, support public health activities, and bring a greater understanding of the interaction of humans with their environment. Because each method can have limits and challenges, a combination best serves public health. Health studies in communities have a role, but these studies should be considered carefully before undertaking them.**

Environmental quality oversight (surveillance) is the systematic testing and reporting to regulatory bodies and to the community of emissions, upset conditions, environmental concentrations, trends, and regulatory compliance and mitigation. Environmental surveillance can also be complemented by population surveillance which is the systematic collection and evaluation of population health data, including biological measures (biomonitoring). Such surveillance programs have been instituted in Ontario in communities with other types of facilities such as nuclear energy installations or in those facilities whose emissions are of particular community concern (*e.g.*, lead smelters). Community concerns can often be addressed by the industry outside of the regulatory framework. **Environmental quality oversight and health surveillance activities constitute engagement of communities with public health agencies (health, environment) and the industry and may be considered part of a responsible program for environmental quality assurance. These surveillance activities can also be coupled with timely responses to community concerns and regular discourse throughout the life of a facility to create a climate of alertness and trust for all parties that can improve facility operations and general well being.**

Energy from Waste Facility in the Region of Durham (Main Report)

Purpose of this report

This work was undertaken at the request of the Medical Officer of Health of Durham Region. Durham Region is currently undergoing a process for siting of an energy from waste (EFW) facility within its boundaries. As part of the process, a generic risk assessment was carried out Jacques Whitford[8]. In the course of public consultation, a number of issues arose regarding the integrity of this generic risk assessment of a "model" facility. The issue of EFW also came under scrutiny as a result of an assessment of health effects of incineration provided to a nearby jurisdiction (Halton Region). The process and conclusions of the health effects assessment became a focus of concern.

Four objectives as outlined in correspondence with the Durham Region Medical Officer of Health are the focus of this report:

A. Provide advice on Section 4a & b (pages 12-15) of the Halton 4a Report[9] (the health assessment, literature search and conclusions arising)

2. What do environmental epidemiology studies of incinerators generally have to say and the pitfalls inherent in these types of studies?

B. Soundness of the Durham generic risk assessment report (in general)

2. Is there any missing information that needs to be reviewed that may have bearing on either the generic or site specific HHRA that will be conducted? (Bioaccumulation of dioxins and furans, *etc*; greenhouse gas emissions, regulatory air quality guidelines / standards, ultra fine particles, *etc*.)

C. An independent comment on risk assessment in general and to what extent does the draft generic HHRA conform to the basic tenets of risk assessment.

D. What are best practices for establishing an environmental monitoring program?

[8] Jacques Whitford. Energy from Waste Generic Risk Assessment Feasibility Study. June 14, 2007 Report # 1009497.02

[9] Regional Municipality of Halton, Step 4A: Identification and Description of Potential Health and Environmental Effects. 30 May 2007. (Consulting Report done under contract to Genivar, Ramboll, Jacques Whitford, Deloitte, URS).

Scope of this report

This consultation to the Medical Officer of Health is limited to the questions posed in the objectives (A, B, C, D) and does not attempt to address any other issues. Dr. Lesbia Smith, hereafter referred to as "the author", examined the three reports: Halton 4a Report, the review of the Halton 4a report health effects section, and the Durham – York Energy from Waste (EFW) Generic Risk Assessment. In order to evaluate the results of the Halton 4a reports and its Review, this author carried out an independent systematic search and critical review of the literature limited to epidemiologic studies on the health impacts of EFW facilities. This systematic search and review are used to answer objective A2 and to evaluate the opinions expressed in the Halton 4a report and its Review. In this report, references used to support opinions and conclusions not related to health impacts of energy from waste were from the most recent peer reviewed literature or summary reviews from academic sources.

Section 1. Précis 10 of Halton Report Step 4A - Chapter 5 Health Concerns Related to EFW Systems[11] **(Objective A – general)**

This report states that the purpose of the literature review is to identify potential health concerns and chemicals of interest that should be evaluated during the planning phase of any proposed Halton EFW facility. The Halton Report Step 4A – Chapter 5 summarizes, but does not provide an interpretation of epidemiological, risk assessment, and biomonitoring literature on municipal waste incineration published from the year 2000 onwards (24 papers/reports). The 4a Chapter 5 also summarized the grey literature and includes studies on hazardous waste incineration facilities and landfill sites.

The authors note that the majority of the pre-2000 published literature on potential health impacts has been conducted on communities around facilities that do not currently have updated pollution control measures. They identified some studies which focused on two facilities that upgraded to modern pollution control technologies.

The report summarized the available literature on health effects organized into studies on cancer, respiratory effects, and reproductive effects. The report also identified the

[10] A précis is a serviceable substitute for a larger work. It is a summary of the essential points of a piece of text.
[11] Genivar, Ramboll, Jacques Whitford, Deloitte, URS. Regional Municipality of Halton: Step 4A: Identification and description of potential health & Environmental Effects., 20 May 2007.

following chemicals of concern: criteria air contaminants (CAC); dioxin/furans; polycyclic aromatic hydrocarbons (PAHs); mercury and other metals. They provide a table summarizing 24 papers/reports on municipal waste incinerators (MWI), grey literature and secondary sources up to the time the report was written (April 2007).

They note and reference a large governmental report [DEFRA 2004][12] that states that even though there have been reports of cancer clusters, there is no published consistent or convincing evidence of a link between incineration and cancer. The authors of DEFRA 2004 note that there was only a limited number of studies that investigated potential respiratory effects from exposure to EFW Systems. Thus, the authors make no conclusion arising from the epidemiological literature on respiratory effects and incineration *per se*. The authors also note that there were only two reproductive studies identified. They indicate the there were adverse reproductive outcomes observed but there are many confounding factors not controlled for in the studies. Overall, the authors conclude that there are potential health concerns but the literature they cited generally involves old incinerators. The authors note that the secondary and grey literature concludes that EFW facilities that utilize modern pollution control measures are not expected to pose a significant risk to public health (*i.e.*, NRC, 1999; NAS, 1999; MOE, 1999; LGA, 2002)[13].

In summary, the Halton Report Step 4A - Chapter 5 Health Concerns Related to EFW Systems examined the peer reviewed epidemiologic literature and grey literature relating incineration and health effects. The literature included original research, review publications and governmental reports. The authors concluded that there are potential health concerns but the literature they cited generally involved old incinerators. The report identified chemicals of concern and agreed with the conclusions of the DEFRA 2004 and other reports that current EFW facilities that utilize modern pollution control measures are not expected to pose a significant risk to public health.

Section 2. Durham generic risk assessment report (Durham – York Residual Waste Study), Report N0. 1009497.02) (Objective B)

The Durham Generic Risk Assessment Study (Durham – York Residual Waste Study, Report N0. 1009497.02) constitutes an exercise in the demonstration of risk assessment processes applied to EFW facility. As a demonstration project, it was able to show the application of a risk assessment framework: making assumptions, modeling exposures, building scenarios, and calculating risk values under different assumptions of emissions

[12] DEFRA (United Kingdom Department for Environment, Food and Rural Affairs), 2004. Review of Environmental and Health Effects of Waste Management: Municipal Solid Waste and Similar Wastes. DEFRAPublications. London,UK.URL: http://www.defra.gov.uk/ENVIRONMENT/WASTE/research/health/pdf/health-report.pdf.

[13] Details of sources are found in the Halton 4a Report.

of the facility and comparing them to regulatory and health benchmarks. It was not intended to be a risk assessment of an actual facility, but rather a demonstration of how the risk assessment methodology would be used with a given technology and site to calculate the risks forecast from the specific facility under a variety of scenarios and normal operating conditions.

This generic risk assessment used standard methodologies and models for air dispersion of emissions, and calculations of risk measured against current regulatory emissions standards in Ontario or health benchmarks. Then the study infers whether a risk is acceptable when compared to the benchmarks chosen. The generic risk assessment did not make calculations of upset conditions, which are believed not to occur in the type of facility currently used (*e.g.,* operations shut down if there is a malfunction.) However, the exposure assumptions made were extreme, and provided a conservative estimate of risks. As one example, the community exposure to dioxins and furans is assumed to occur for the lifetime of the person living in the area and the concentrations in the environment are considered at the level attained after 35 years of facility operations.

The report is limited, as are all risk assessments, in that it did not make calculations for complex mixture exposures, unless such mixtures are already regulated as such (i.e., PAHs, dioxins and furans). It did not consider particulate exposure unless the particulate is characterized and regulated (i.e., PM_{10} and $PM_{2.5}$). Hence the issue of ultrafine particulates or "nanoparticles" exposure was not and could not be addressed as a regulated toxic exposure; there are no specific risk assessment techniques or sufficient toxicological information available currently to do so.[14] Therefore this is not a failing of the risk assessment methods used or of this report per se.[15,16]

Very little is known about the health effects associated specifically with exposure to the by-products of combustion of hazardous wastes. Hazardous wastes may produce pollutants in ultrafine size under 2.5 microns of variable composition. These particles may contain variable amounts of carbon, iron, potassium, silicon, copper, nickel and zinc. The chemical nature of these particles has not been characterized but is in a form that is reactive with tissues under in experimental conditions.

Epidemiologic studies of air pollution particulate matter consider only those particles that are measured by current instrumentation, PM10 and PM 2.5. There is currently no measurements of ultrafine and nanoparticles in air or any regulatory measures. Hence, they are not considered as a specific exposure in EFW risk assessments. It should be

[14] Cormier SA, Lomnicki S, Backes W, Dellinger B, 2006. Origin and health impacts of emissions of toxic by-products and fine particles from combustion and thermal treatment of hazardous wastes and materials. Environmental Health Perspectives. Jun; 114(6):810-7.
[15] Grahame T, Schlesinger RB. Health Effects of Airborne Particulate Matter: Do we know enough to consider regulating specific particle types or sources? Inhalation Toxicology 2007;19(6):457-481.
[16] Westheit DB, Borm OA, Hennes, C, Lademann J. Testing strategies to establish the safety of nanomaterials. Conclusions of an ECETOC Workshop. Inhalation Toxicology 2007;19(8):631-643.

noted that these ultrafine and nanoparticles are emissions of concern from hazardous waste incineration, as opposed to municipal EFW facilities. [17] Dioxins are produced de novo from incineration regardless of what is burned. Plastics are destroyed completely by combustion and any recombination into polychlorinated aromatic compounds that occurs in the burning process is dealt with in the emissions control technology.

The report makes assumptions of susceptibility by using the health benchmarks applicable to the most vulnerable in the community in the different scenarios. Any future risk assessment should address exposures with upset conditions if this scenario applies to the technology used. The peer review of this Draft Report identified a number of issues which once addressed, make the report a professional and complete demonstration of a model of the generic risk assessment method applied to an EFW facility.

In summary, the generic risk assessment was properly carried out. The methods used were clearly explained and therefore, the entire exercise can be duplicated by other investigators. As expected, it erred on the side of health protection or "conservatism". Ultrafine particulate and nanoparticle exposure were not considered as there are currently no risk assessment methods to do so.

Section 3. Précis of the Review/Critique of the Halton 4a Report and Issues Arising **(Objective A – general)**

The Halton 4a Report was reviewed by an external expert on behalf of the Halton Medical Officer of Health. The Review/Critique of the Halton 4a Report focuses on its flaws and dismisses any strength. The reviewer noted that the health effects analysis is flawed in a number of areas: literature search method, interpretation of results of studies, ignoring studies related to landfill sites which have "a demonstrated risk of congenital anomalies", failure to show the historical trends in lower emissions from EFW facilities with actual data, failure to consider food as a pathway of exposure, failure to consider sensitive populations, failure to consider a suite of different than "standard" health outcomes, and failure to consider the potential health impacts from upset or normal operating conditions releasing chemicals with potentially acute impacts (*e.g.*, NO_2, particulates).

An important point made by the reviewer is that the 4a Report does not appropriately distinguish the functions of risk assessment as "prescriptive" (sic); (the reviewer here means predictive or prospective- before the fact)[18], and epidemiology being "diagnostic" (sic); (the reviewer here means measured or retrospective – after the fact); and the

[17] Cormier SA, Lomnicki S, Backes W, Dellinger B, 2006. Origin and health impacts of emissions of toxic by-products and fine particles from combustion and thermal treatment of hazardous wastes and materials. Environmental Health Perspectives. Jun; 114(6):810-7.
[18] This author's interpretation of the usage in the Review/Critique of the Halton 4a Report.

different inferences that can be made from each method. The reviewer concludes that the authors of the Halton 4a Report do not define all potential health risks from an EFW facility especially for criteria pollutants, and that these potential health risks must be examined with a site specific risk assessment considering local background (air pollution) and emission rates specific to any proposed facility or technology. However, the reviewer did not come to any different conclusions but states that other health outcomes should be considered or how this could be done.

The appropriate evaluation of health risks for an EFW facility remains an issue insofar as neither the Halton Report 4a nor the Review/Critique provides a definitive answer on health effects arising from the epidemiology. The Review/Critique itself did not carry out a literature search to compare findings with the Halton 4a Report. It did add some publications for discussion (Amalendu and Bigger) but fails to provide a reference and any relevant information therein.[19]

In summary, aside from trivial matters of grammar, syntax, and spelling (including one reference in the text -"Fiedler"- which is correctly referenced in the documentation as "Fielder"), criticisms of the literature review carried out for the 4a Halton Report centered about four issues: 1) what constitutes a systematic literature search (including rationale for limits of the search); 2) what constitutes primary vs. secondary literature; 3) failure to provide criteria for inclusion and evaluation of studies; 4) failure to state clearly the limits of epidemiology in evaluating health effects to the community living around incineration facilities and the limits of the conclusions that can be made. The Review/Critique did not demonstrate how correcting these would make a material difference in the findings.

Section 4. Literature Search of Health effects from Energy from Waste Facilities **(Objective A1 – documentation of the incineration and health effects literature)**

Rationale

This report presents the results of a systematic search analysis of the epidemiologic literature on incineration and human health effects. The author hopes that such a review can document health effects from incineration in a transparent manner and correct any misinformation which could have arisen from either the Halton 4A Report or the Review/Critique of it.

[19] This author failed to find this or these references (Amalendu and Bigger) in two data base searches.

No systematic search can capture all studies. Hence, some reports included here may not have been found in searches done by others. Of those studies captured in this search, the author made an effort to include in the critical review only those studies that met rigorous *a priori* criteria[20] for worthiness to use in a weight of evidence evaluation of the relationship. The rigorous criteria reflect the guidelines for systematic reviews described in the Cochrane Collaboration Handbook[21], five of which guided this review:

- The methods used in a review should be selected to optimize the likelihood that the results will provide the best current evidence upon which to base decisions.
- It is important to let people know when there is no reliable evidence, or no evidence about particular outcomes that are likely to be important to decision makers.
- It is not helpful to include evidence for which there is a high risk of bias in a review, even if there is no better evidence.
- Similarly, it is not helpful to focus on trivial outcomes simply because those are what researchers have chosen to measure.
- So far as is possible, it is important to take an international perspective. The evidence collected should not be restricted by nationality or language without good reason.

The objective of this new literature review is to identify relevant epidemiological literature on the health effects of municipal waste incineration independently from the Halton 4a Report and the Review/Critique of that report and add any new studies not previously captured. Both the search and the selection and evaluation of studies were approached with an *a priori* algorithms and criteria for searching, including and excluding, evaluating, and synthesizing the results of the studies resulting from the systematic search.

Limits were set for a publication date between January 1, 2000 and July 13, 2007. The dates were made to concur with the Halton 4a Report plus an additional 3 months which had passed since the Halton 4a Report search was done. These dates would include studies of incinerators using up to date or upgraded technology, or would be of populations impacted for long periods of time. This is important as chronic health effects are more coherent if there is consideration of latency. (Latency is the interval between sufficient exposure occurs to induce disease and the manifestation of the disease.) Through the use of back referencing from recent studies, it is be possible to identify

[20] See Appendix I for criteria for inclusion and evaluation of epidemiologic of studies.

[21] Higgins JPT, Green S, editors. Cochrane Handbook for Systematic Reviews of Interventions 4.2.5 [updated May 2005]. In: The Cochrane Library, Issue 3, 2005. Chichester, UK: John Wiley & Sons, Ltd.

studies worthy of inclusion (*e.g.*, Elliott 1996) in the final assessment of the evidence or to identify others potentially missed by the search. The resulting literature was evaluated independently by this research team against an assessment framework and rated using an *a priori* rating scale recommended in the evaluation literature.[22,23] Ratings for each publication were on a scale of 1 to 3 for various study characteristics (lowest quality to highest quality). Those with a rating of greater than two (out of three) were included in the summary review. The results of the literature review, the rating scale and review process are discussed in more detail in *Appendix I and II*.

To summarize, this literature review included the steps outlined below:

1. Review of the Halton 4A report (Chapter 5 Health Effects Section).
2. Develop a set of search terms and keywords to conduct the literature search.
3. Search relevant scientific literature databases for studies, and other potentially relevant scientific information in key publications.
4. Systematically include relevant studies and exclude uninformative studies.
5. Systematically assess each of the included studies.
6. Synthesize the results.

The search terms were derived from the Halton 4a Report and this author's experience with the literature in this area. The search parameters, with no exclusion limits, were applied to, and re-run on, three scientific literature databases: MedLine, ToxLine, and Environmental Sciences and Pollution Management. The search was run first in MedLine, where 135 articles were identified as potentially relevant. When all the inclusion and exclusion criteria were applied, 25 articles were retained for full-text review. When the same search parameters were re-run on the other databases (ToxLine, and Environmental Sciences and Pollution Management), 2 articles not identified in the MedLine search were included for full-text review.

Upon closer examination, 8 publications were deemed to have a study focus not relevant to municipal waste incineration, and 4 articles were unavailable from the library. (We have abstracts for these.) This left 15 articles remaining from the search of scientific databases. Upon review of references ("back referencing"), an additional 2 relevant papers that had not previously been identified were deemed relevant for inclusion in the final review.

In summary, the systematic search and abstract review of relevant databases identified 17 publications which were of populations living around incinerators. Of these 17 publications, 3 were review articles and 14 were original research submitted to detailed critical assessment. Six of the 17 articles were included in the results of the search in the

[22] Oxman AD, Guyatt GH. Guidelines for reading literature reviews. CMAJ. 1988 Apr 15;138(8):697-703.1988.
[23] Higgins JPT, Green S, editors. Cochrane Handbook for Systematic Reviews of Interventions 4.2.5 [updated May 2005]. In: The Cochrane Library, Issue 3, 2005. Chichester, UK: John Wiley & Sons, Ltd.

4A report. Eleven of the 17 were newly identified in our literature search. Of these eleven, two were in the list of references of the Halton 4a Report. (The differences between the results of the two searches may be attributable to the 4 month interval between the searches.) Abstracts of potentially relevant papers referenced in the Halton 4a report were examined but not evaluated by the critical assessment schema (*e.g.*, Gonzalez et al, 2000 which uses composite blood levels of contaminants from groups of residents, not from individuals.[24])

A structured abstraction form was used to analyze and summarize the 14 original research articles (Appendix I: Table 1). An assessment of each study was made using criteria on the study design, exposure assessment and effects assessment (Appendix I: Table 2). Studies that rated medium to high (≥ 2 as an average out of a maximum of 3) for 3 categories of methods, exposure and outcome measures were considered. Because it is not helpful to include evidence for which upon review, there is a high risk of bias, even if there is no better evidence, only the strongest studies were considered for the discussion on the health effects from municipal waste incinerators.

It is important to note that none of the studies evaluated achieved full marks on all of the *a priori* scoring scale of study and control population definition, exposure assessment and outcome assessment. A discussion of the reasons for this is presented in the Epidemiology section on page 19. The abstractions and evaluations of each publication are presented in Appendix *III*.

Three review articles (not abstracted) referencing many previous publications were also examined. Rushton (2003) reviewed 48 references on multiple forms of waste management, including incineration. Hu and Shy (2001)[25] reviewed 28 references on epidemiological studies (including waste workers) on the health effects of waste incinerators. Francini et al. (2004) reviewed 72 references.

All three reviews are a summary of the literature; they did not indicate that they conducted a formal critical appraisal of each of the studies. Nonetheless, the authors' narratives indicate that they considered an evaluation of methods and inferences from each paper in order to formulate conclusions.

Rushton (2003) and Hu and Shy (2001) note that there are inconsistent results for cancer and reproductive outcomes. Francini et al. (2004) concludes that many studies show an association between incinerators and various cancer endpoints and birth defects. These

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[24] Gonzalez CA, Kogevinas M, Gadea E, Huici A, Bosch A, Bleda MJ, Papke O, 2000. Biomonitoring study of people living near or working at a municipal solid-waste incinerator before and after two years of operation. Archives of Environmental Health. Jul-Aug; 5(4):259-67.

[25] This article was not available electronically or through interlibrary loan. Secondary sources and the abstracts were used to summarize the authors' conclusions and recommendations.

three reviews note that very few studies find an effect between incinerators and respiratory effects.

The review publications have some common conclusions in summarizing their collected literature on the health effects of incinerators. All three review articles note the significant limitations in the studies; in particular: the fact that the majority of the studies occurred in areas around old technology incinerators; most studies use proxy measures of exposure to the incinerator (for example, distance of home or school to the incinerator); critical confounding factors are rarely considered (for example, occupational exposures; smoking status; SES; other sources of exposures of interest in the vicinity; movement in and out of study area; latency of effects). All reviewers note that there may be health effects from the incinerators, but that these have not be demonstrated by the epidemiology. All studies call for improved measures of exposures and effects.

One governmental report (DEFRA, 2004) also examined incineration health effects and concluded similarly:

- Current limitations of studies make it difficult to detect impacts
    - Multiple routes of exposure
    - Exposed populations too small
    - Incineration emissions are a complex mixture of contaminants
    - Other sources of the same contaminants in the area (combustion sources – cars/trucks, industrial activity, coal fire energy plants, forest fires, household fires, etc.)
    - Generally non-specific health outcomes

Section 5. Analysis and Results of the Literature Review

The literature was evaluated using critical appraisal criteria, summarized, and inferences made based causal inference criteria. Details of the process are in Appendix III.

The recent epidemiologic literature relating health effects in communities close to municipal waste incinerators is limited in quantity, scope, and consistent methodological quality. Any health effects postulated to be related to incinerator emissions must be *coherent* with the exposures from incinerators. However, the majority of studies do not document exposure appropriately to satisfy this criterion. The methodology used by studies is usually cross sectional; and no cohort study and only one case control study was identified. There are additional challenges in that populations around incinerators are limited in number and the outcomes of interest are usually distilled to those that can be obtained from available population data (birth defects, birth weight, and cancer) or

from less reliable self-reports (surveys). Some of these outcomes have relatively low frequencies such that power to detect differences is difficult – the lower the frequency, the larger the population required to find statistically significant changes from baseline or among exposed and unexposed populations. Thus, studies of incinerators do not satisfy the criteria for magnitude of risk (*direction and strength of association between exposure and risk*) and *consistency* of results across populations. They assume but do not examine *temporal sequence* (of exposure preceding the outcome with appropriate latency for the effect) or in many cases, *theoretical or biologic coherence*.

Other papers supplementing those resulting from our search were also examined for relevance in making the conclusions above. Glorennec et al[26] conclude that after compliance to incinerator emissions, all hazard ratios and future individual lifetime risks appear minimal. Even though not all information on environmental transport is available for dioxins, they state that compliance has "vastly reduced the probability of health effects".

Epidemiology as practiced in environmental settings of low level exposure appears to have intrinsic limits in its ability to *attribute* health effects to a particular exposure. This is very much in contrast to studies of occupational environments where higher exposures to limited chemicals of concern tend to occur and there are usually good to excellent measures of ambient contaminant levels. A very large body of evidence which examines the relationship between exposures and health effects in a variety of settings, both occupational and environmental, can provide sufficient information to infer relationships. That is not the case with the literature on modern incinerators; it is limited. Therefore action must be based on predictive methods such as risk assessment. (See Section 5, below) and not on the body of epidemiological studies which are largely inconclusive.

Biomonitoring of populations around modern or upgraded incinerators has provided a good baseline for contaminant load, the literature overall cannot be used to support or dismiss possible health effects or the attributable load of contaminants emitted from current modern incinerators.

In summary, this author concludes that the current epidemiologic literature does not demonstrate one way or another that modern incinerators have health effects on the people living around them. This conclusion concurs with the conclusions of the three review publications, and is not materially different from the conclusions of the Halton 4a Report.

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[26] Glorennec P, Zmirou D, Bard D, 2005. Public health benefits of compliance with current E.U. emissions standards for municipal waste incinerators: a health risk assessment with the CalTox multimedia exposure model. Environment International. Jul; 31(5):693-701.

Section 6: Risk Assessment and Epidemiology (Objective C)

Risk Assessment

Risk assessment is the only method that can make a prospective evaluation of risk of a given facility. Risk assessment and exposure modeling can have an advantage over epidemiology and biomonitoring in that the risk assessment can be used to draw direct links between emissions sources of interest and exposure pathways to a particular receptor (*e.g.,* child, pregnant woman). There are limits however, in that risk assessment does not evaluate complex mixtures very well because there are few empirical data to do so. In order to address risks from exposure to chemical mixtures, risk assessment typically relies on the assumption of adding doses of similar chemicals together (dose additivity), or adding together similar effects (effect additivity) of one or more chemicals. Summing the dose of PAHs and assuming that all of the PAH-related compounds are as toxic as the most toxic (*i.e*. benzo(a)pyrene) is an example of dose additivity as used in risk assessment. Summing the toxicity of dioxins by using a toxic equivalent for each dioxin compound and adding the toxicity equivalents is an example of effect additivity. (The toxic equivalent measure takes into consideration the dose and the effect.) Summing up the total cancer risk from exposure to several carcinogens is an example of effect additivity as well. While this process might underestimate some interactions (*i.e.,* non-additive interactions), it is generally assumed within the risk assessment community that assuming additivity is conservative and public health protective. It is always assumed that substances emitted are toxic, and no allowance is made for positive effects that may negate adverse health effects.

Limitations and Strengths of Risk Assessment in Failure and Upset Conditions

This literature review did not identify any studies that examined the health effects from incineration failure or upset conditions. The 4a Report identified a study that modeled air concentrations of metals assuming an emergency bypass of the air pollution control equipment (Hasellriis and Wood, 1998)[27]. The study concluded that the resulting increase

[27] Hasselriis F, Wood R, 1998. Evaluation of the potential for health effects due to short-term emissions of metals from incinerators. Environmental Engineering Science; 15 (2). 149-156.

of modeled metal concentrations met acceptable acute risk values. This study was not critically appraised for this project. A risk assessment for a proposed incinerator should be designed to assess failure and upset conditions and compare these values to both acute and chronic risk values. The risk assessment method can make calculations of risk for failure and upset conditions and can put boundaries on actions to take to mitigate exposures to residents around the facility. However, modern incinerators are unlikely to experience these so called upset events because the system is shut off if there is a potential malfunction.

Epidemiology

Epidemiology is a research method which is best described as a measurement exercise. It measures the relationship between exposures to chemicals (or environmental conditions) and some characteristic of health, usually a disease state or condition. Epidemiology methods are either experimental or observational. Experimental studies such as clinical trials, or controlled laboratory experiments, can measure risks precisely because the dose given to the subjects is controlled by the experimenter, and the health effects are observed and measured carefully during the period of observation of the subjects.

Environmental epidemiological studies are non-experimental or observational. These studies do not have exposures under experimental control and observations are made non-concurrently (i.e., long after both the exposure and the outcome have occurred). They can only use exposure measurements of what already exists rather than concurrent direct measures – and sometimes these are "proxy measures" which are far from exact, such as "distance from a facility". (Distance makes an intrinsic assumption of air dispersion of contaminants that posits that concentrations exposure will vary with distance from the emissions source and exposure will vary with environmental concentrations.) The use of air dispersion models to define exposure of groups and can improve on the use of distance as the exposure measure. Unless the model is applied to individuals rather than a group of people, the methodology still has a basic flaw, the ecologic fallacy – the flaw of attributing to individuals the characteristics of the group.

The measurement of health effects is also limited by the existing and available data. A study is only as good for inferring potential causal associations as its design, how well it explains exposure and outcome measures, accounts for competing exposures, considers other risk factors, and accounts for data limitations. Hence, there are well executed studies which are cross sectional and give us limited information, and others which are of a higher order of potential precision of risk measures (*e.g.,* cohort study) but are not well carried out. Each one can give different information, and make possible inferences about causation.

In summary, the epidemiologic method, being observational in environmental settings, is limited: statistical associations between an exposure and an outcome alone do not make a causal relationship. Unlike one good clinical trial, a single well conducted environmental epidemiology study does not necessarily make a causal relationship between an exposure and a health effect, even if a relationship is found.

Making causal links with epidemiology as the only tool requires many studies examining a relationship from different perspectives. It is not how many studies, but rather their methodology, how well they are conducted, what information can be derived with certainty, and what is the weight of all of the evidence for all studies together.

Critical assessment of environmental epidemiology studies and systematic review of the results are necessary to direct the reader to an appropriate interpretation on the consistency of the overall literature. (The reader must also consider publication bias,[28] which is rarely analyzed in environmental epidemiology reviews and will not be discussed here, as the literature is scant. The Cochrane Collaboration handbook states that many researchers have shown that those studies with significant, positive, results are easier to find than those with non-significant or 'negative' results. The subsequent over-representation of positive studies in systematic reviews may mean that our reviews are biased toward a positive result.) The net results of systematic literature reviews should then be viewed with yet another lens, that of inferring causality from a set of consistent associations that make sense and are coherent with other observations and with experimental data. There are various sets of criteria used for that process, but the most commonly used in occupational and environmental settings are the criteria of Bradford Hill.[29,30]

Biomonitoring

Biomonitoring reflects total exposure of a person to a contaminant without providing information on the source or exposure pathway. For example, measuring lead in blood does not tell us if the lead came from a hobby, food, or air pollution. For contaminants such as PAHs, whose sources for a typical person are numerous (barbecued foods, forest fires, and industrial emissions); biomonitoring may not provide the information necessary to develop effective risk management strategies. That is, if one does not know where it

[28]The Cochrane Collaboration open learning materials. August 9, 2007 http://www.cochrane-net.org/openlearning/html/mod15-2.htm

[29] Hill AB. (1965). The environment and disease: association or causation? *Proceedings of the Royal Society of Medicine*, 58, 295-300.

[30] The Bradford Hill criteria include strength and direction of an association, dose response, temporal sequence, consistency, theoretical plausibility, biologic coherence, specificity of effect, analogy and experiment.

originates, one cannot intervene in the pathway to prevent the exposure. For a contaminant that only arises from a specific emissions source, biomonitoring can be a useful measure as it can be attributed to that source very specifically. One example of this is isotopic measurement of lead to compare facility emissions isotopes with lead isotopes in the environment from other sources such as gasoline or paint. Biomonitoring is very useful, however, in relating total exposure (from all sources) to health conditions in well executed and controlled epidemiological studies.

Summary of risk assessment, epidemiology and biomonitoring

By using risk assessment methodology and information from epidemiology, coupled by direct measurement of exposures (biomonitoring) in the appropriate setting, greater precision can be achieved in calculating exposure from environmental contaminants and health effects in populations. All three methods assist regulatory bodies, support public health activities, and bring a greater understanding of the interaction of humans with their environment. Because each method can have limits and challenges, a combination best serves public health.

Section 7. What are best practices for establishing an environmental monitoring program? (Objective D)

Once an industry has been introduced into an area, the community will perceive health experience as related to it. These perceptions are difficult to dispel. Health studies can sometimes assist in understanding the relationships between health effects experienced and environmental contaminants at a local level. The health experience of a community will depend on many factors, environmental quality being one important but relatively small component in regulated environments and is very difficult to measure. Hence, more often than not, studies are inconclusive. Community health surveys can enumerate health problems or health status from information provided by the participant, but cannot attribute causes of health effects to low level environmental contaminant exposure. This is especially so when the local industry may be but one source of a particular contaminant (*e.g.,* dioxins and furans)

Notwithstanding, there are many publications that report results of studies carried out in "incinerator communities" as part of environmental health surveillance.[31,32,33,34, 35] These studies are usually carried out under the sponsorship of public health departments. They include health surveys of respiratory symptoms and other health complaints, and biological monitoring for metals and dioxins/furans, since these chemicals are relevant to EFW (incinerator) emissions.

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[31] Reis M, Sampaio C, Brantes A, Aniceto P, Melim M, Cardoso L, Gabriel C, Simao F, Miguel JP, 2007c. 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. International Journal of Hygiene and Environmental Health. Feb 24; [Epub ahead of print].

[32] Reis M, Sampaio C, Brantes A, Aniceto P, Melim M, Cardoso L, Gabriel C, Simao F, Pereira Miguel J, 2007d. 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. International Journal of Hygiene and Environmental Health. Feb 28; [Epub ahead of print]

[33] Reis MF, Miguel JP, Sampaio C, Aguiar P, Melim JM, Papke O, 2007b. Determinants of dioxins and furans in blood of non-occupationally exposed populations living near Portuguese solid waste incinerators. Chemosphere. 2007 Jan 19; [Epub ahead of print].

[34] Reis MF, Sampaio C, Aguiar P, Mauricio Melim J, Pereira Miguel J, Papke O, 2007a. Biomonitoring of PCDD/Fs in populations living near Portuguese solid waste incinerators: Levels in human milk. Chemosphere. 2007 Jan 8; [Epub ahead of print].

35 Miyake, Y., A. Yura, et al. (2005). "Relationship between distance of schools from the nearest municipal waste incineration plant and child health in Japan." European Journal of Epidemiology 20(12): 1023-9.

Communities often request that health studies be conducted to examine if a facility has had an impact on health. Often, a "baseline" health study is requested at the onset of facility operations to be repeated sometime later. Sometimes communities ask for specific prevalence surveys of symptoms of concern such as respiratory symptoms, annoyance conditions such as odors, or cancer. While some of these studies are useful, one must be clear about the question that each type of study purports to answer. None of these studies on its own can answer the question that communities ask: "Has this facility caused this particular health effect?" The limits of single studies in epidemiology emphasize their potential lack of usefulness in community settings with low or very low level of exposures. Hence, they must be carefully designed and executed with a critical look at objectives and methodology.

Surveillance of community exposure is best done prudently, that is by ensuring that exposure does not occur beyond what is safely allowed, and in principle, not associated with adverse health effects beyond background rates. This accounts for the importance of environmental surveillance, which is the systematic testing and reporting of emissions in normal and upset conditions (if applicable), environmental concentrations of key emissions, trends in concentrations, industry performance, and regulatory compliance. This type of program has been instituted in Ontario in communities with other types of facilities such as nuclear energy installations and in places where facilities have other emissions that are of particular community concern. These activities engage communities with public health, regulatory agencies, and industry; the activities may be considered environmental surveillance. With engagement of all parties, community concerns can often be addressed by the industry itself even outside of the regulatory framework. Industry can provide benefits that have value to the community, such as recreational areas, gardens, etc. These surveillance activities can also be coupled with timely responses to community concerns and regular discourse throughout the life of the facility to create a climate of alertness and trust that can improve general well being.

In short, community surveillance can take the form of environmental monitoring and reporting, timely responses to health concerns, and continued engagement with communities throughout the life of the facility. Health studies in communities have their role, but these studies should be considered carefully before undertaking them.

Appendix I: Search Strategy and Results of Searches

Search Strategy and Results of Searches

The focus of this review is to identify relevant epidemiological literature on the health effects of municipal waste incineration with a publication date between January 1, 2000 and July 13, 2007. The relevant literature was evaluated independently by the research team against an assessment framework and rated using an *a priori* rating scale recommended in the evaluation literature.[36,37] Ratings were on a scale of 1 to 3 (lowest to highest quality) for various study parameters. Those with a rating of greater than two (out of three) were included in the review. The rating scale and review process are discussed in more detail in the following sections.

In keeping with the guidelines for systematic reviews described in the Cochrane Collaboration Handbook, five of the handbook criteria guided this review:

- The methods used in a review should be selected to optimize the likelihood that the results will provide the best current evidence upon which to base decisions.
- It is important to let people know when there is no reliable evidence, or no evidence about particular outcomes that are likely to be important to decision makers.
- It is not helpful to include evidence for which there is a high risk of bias in a review, even if there is no better evidence.
- Similarly, it is not helpful to focus on trivial outcomes simply because those are what researchers have chosen to measure.
- So far as is possible, it is important to take an international perspective. The evidence collected should not be restricted by nationality or language without good reason.

Thus, this literature review required a number or steps outlined below:

1. Examine the 4A report
2. Examine seminal reports from the grey literature.
3. Develop a set of search terms and keywords to conduct the literature search.
4. Systematically search relevant scientific databases for studies, and other potentially relevant scientific information in key publications.
5. Systematically include relevant studies.

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36 Oxman AD, Guyatt GH. Guidelines for reading literature reviews. CMAJ. 1988 Apr 15;138(8):697-703.1988.
37 Higgins JPT, Green S, editors. Cochrane Handbook for Systematic Reviews of Interventions 4.2.5 [updated May 2005]. In: The Cochrane Library, Issue 3, 2005. Chichester, UK: John Wiley & Sons, Ltd.

6. Systematically assess each of the relevant studies.

Literature Search

The first step involved the development of a set of key words to conduct the literature search (including authors identified). Some of the search terms/phrases are identified below (see Figure 1 for a complete list).

- Refuse Disposal, Incineration, Bioelectric energy sources, Energy from waste (keyword), Municipal waste incineration (keyword)
- Environmental exposure, Inhalation exposure, Maternal exposure, Paternal exposure
- Risk assessment, Risk factors, Risk assessment, Risk
- Health hazards (keyword), Health effects (keyword)

Searches of three scientific literature databases were carried out independently. The search was limited to articles published on or after the year 2000. This review is intended to identify health effects associated with current incinerator technologies. The limits to year 2000 to current allow studies of communities around older facilities to have had sufficient time for exposures to have occurred (latency criterion for long term health effects). Even if studies are published recently, the populations they describe may have resided around operations that may have existed for many years. Hence, studies potentially would not cover only modern EFW technology. The rationale for excluding non- English literature is that EFW literature tends to be published the English scientific press, or summarized in English databases even if the original is in another language. In addition, the timely acquisition and translation of foreign language papers is often challenging for projects such as this requiring timely access. This author's opinion is that this does not hamper making appropriate conclusions from the English literature obtained. We used back referencing but did not carry out any author name search as part of the search and selection process.

The search parameters, with no exclusion limits, were applied to, and re-run on, three scientific literature databases: MedLine, ToxLine, and Environmental Sciences and Pollution Management. The search was run first in MedLine, where 135 articles were identified as potentially relevant. When the exclusion criteria were applied, 87 potentially relevant articles remained. The exclusion criteria were: not published between 2000 and 2007, not published in the English language, and not human study subjects. Where available, abstracts were reviewed and articles focussing on the following topics were excluded: household biomass fuels, radioactive waste, toxic waste, medical waste, hazardous waste, agricultural waste, landfills, occupational health and safety of waste workers, comments and letters, and other articles deemed not relevant (not about municipal waste incineration). Where abstracts were not available, relevance

was assessed based on the title of the article. Following this step, 25 articles were retained for full-text review.

When the same search parameters were re-run on the other databases (ToxLine, and Environmental Sciences and Pollution Management), 2 articles not identified in the MedLine search were included for full-text review.

Upon closer examination, the remaining 8 articles were deemed to have a study focus not relevant to municipal waste incineration, and 4 articles were unobtainable from the library. This left 15 articles remaining from the search of scientific databases. Upon review of references, an additional 2 relevant papers that had not previously been identified were deemed relevant for inclusion in the final review. Of the four unobtainable papers, 2 abstracts were examined but not evaluated by the critical assessment schema.

The 17 papers included in the final stage of the review examined systematically for information upon which inferences on association and/or causality can be drawn. A structured abstraction form was used to ensure consistency of data collection (explained in more detail in the following sections). The assessment was made on the basis of the criteria described in the following sections.

In summary, the systematic search and abstract review of relevant databases identified 17 relevant papers submitted to detailed critical assessment. Two papers were assessed only from their abstracts and two were unobtainable from the library.

Summary Results of the Search for Relevant Articles

- 14 articles retrieved from the primary literature published between 2000 and 2007.
- 11 unique studies
- Countries studied: Korea, Portugal, France (2), UK (2), Japan (2), Taiwan
- Two studies (five publications) were identified that examined either a new incinerator or one retrofitted with pollution control technology (Ries et al., 2007a;b;c;d; Lin et al., 2006)
- Four studies examined reproductive/developmental outcomes (for example, congenital abnormalities; low birth weight; infant deaths) (Cordier et al. 2004, Dummer et al. 2003, Lin et al. 2006, Tango et al. 2005).
- Three studies examined cancer endpoints (liver – Elliot et al. 2000; non-Hodgkin's lymphoma – Floret et al. 2003, Viel et al. 2000; and soft tissue sarcoma – Viel et al. 2000).
- 1 study examined respiratory/allergic outcomes (Miyake et al. 2005).
- 2 studies (used biomonitoring as a measure to examine the possible impact of the incinerator (milk – Tajimi et al. 2005, blood for metals and dioxins/furans – Reis et al a, b, c, d; Leem et al. 2003).

Process and Results

MedLine: (See Figure 1 for search terms and results)

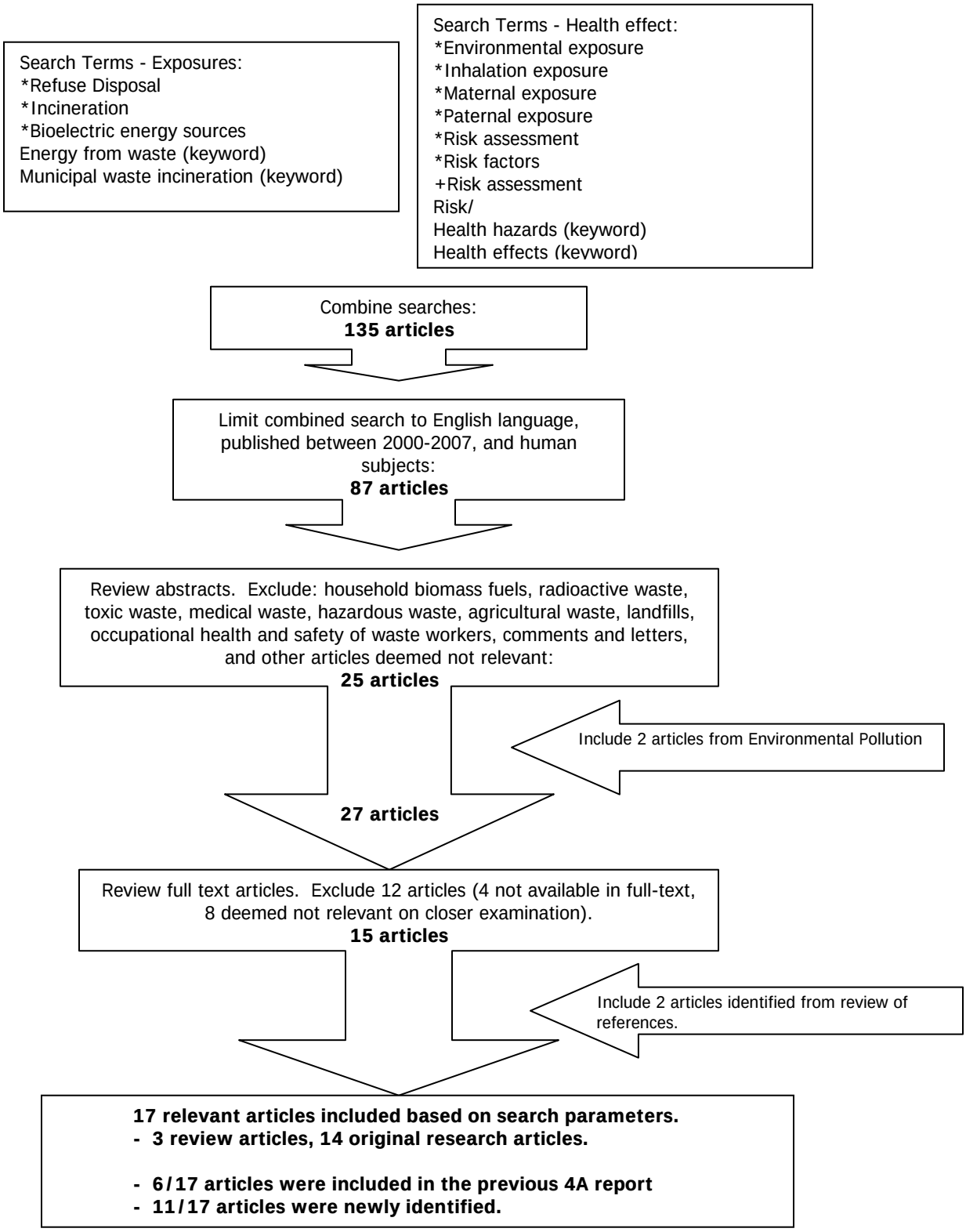
TOXLINE & Environmental Sciences and Pollution Management Databases:

Search parameters:
(Energy from waste OR Incineration) AND (Health Effect OR Health Hazard OR Risk)
Limit to 2000-2007

Results:
TOXLINE : 49 articles returned, 0 articles not present in MedLine search
ESPM : 64 articles returned, 1 articles not present in Medline search.

Figure 1 depicts the process and results.

Figure 1: Health effects associated with energy from waste technologies: Literature search methods & Results



Appendix II: Critical Appraisal Methods and Evaluations of Publications

Critical Appraisal Methods and Evaluations of Publications

Framework for Assessing Literature

A review of the citations and abstracts retrieved from electronic database searches was carried out to determine the potential relevance of each article. A copy of each publication that appeared to offer potentially relevant and useful information was obtained. The following criteria determined relevance:

- The study population included human subjects;
- Exposure to municipal waste incineration by-products was explicitly studied;
- The outcome of interest was a human health effect or biological measure.

The summaries of the publications selected for review are presented in Appendix IV.

In order to evaluate the strengths and weaknesses of each study, a matrix was developed for a systematic assessment. Such matrices have been published by a number of academic groups to assist reviewers in this task. One such matrix was used and is detailed below (Table 1). The purpose of this task is to generally assess the study's methods, and describe the characteristics of the population, exposure and outcome measures used to prioritize studies according to these characteristics.

As a general guide, the following characteristics are used in examining epidemiological studies. Not all of these criteria necessarily apply to each publication. However, each publication is examined with respect to all of the criteria.

Characteristics examined in the critical evaluation of publications[38]

- Does the title of this paper accurately reflect the main scope and nature of the work?
- Is the abstract a well structured, accurate and balanced summary of the work?
- Does the abstract distinguish between the results and the conclusions drawn?
- Are the objectives specific and clearly stated in the introduction?
- Do the objectives raise hypotheses or test hypotheses?
- What methodological approach was used for the study? (cross sectional, cohort, case control)
- Was the method appropriate to meet the objectives?
- Was the study "population" clearly defined?
- Is the studied population representative of the group from which it is drawn?
- How satisfactory was its sampling?
- How was the sample size chosen?
- How has the information been obtained?
- Have sources of data been clearly described?
- Have they been validated?
- Are they reproducible?
- Could they have been biased?
- Is quality control of collection of information mentioned?
- Are controls appropriate?
- How distinct from the cases were the controls?
- Could there have been misclassification of exposure or disease status?
- Has matching been carried out correctly?
- How well was exposure assessed? (*i.e*. characterized as to its identity, and other relevant co-exposures assessed)?
- How was it measured?
- How well was it quantified?
- Was it studied in such a way as to explore a possible exposure-response relationship?
- Were statistical methods appropriate and necessary?
- Could chance have been responsible for the results?
- Are there unique other issues with the study methods that warrant special attention
- Do the results appear in enough detail to permit some checking for accuracy (between the text, tables, figures etc)?

38 Health, Environment and Work Resources. Critical Appraisal of Environmental and Occupational Health Literature; July 2007 http://www.agius.com/hew/

- Are the results consistent?
- Are the results detailed enough to justify the conclusions?
- If appropriate, are they consistent with an exposure-response relationship?
- Are response rates quoted?
- Could a poor response rate hide the possibility of important bias?
- What are the most important sources of bias? i.e. interviewer, observer, recall, selection, response, etc.
- Are the conclusions consistent with the reported results? Are they plausible?
- Were the sources, direction and magnitude of bias adequately discussed?
- Have the confounders been adequately considered?
- Could other conclusions be drawn from the same results? (*e.g.* if they rely on temporality alone).
- Has there been an adequate comparison with other relevant literature?
- How relevant were the study population and conditions of exposure to the conclusions drawn?
- Is the source of the reference clear?
- Are the authors and their affiliation clear?
- Where can further information be sought?
- How differently would you have undertaken a study to fulfil the same objectives?
- Why did the authors not follow the approach you might have advocated?
- What other information would you seek about this particular study?
- What other information would you seek to corroborate or refute the conclusions of this particular study?
- Is this study likely to make a difference in relation to understanding or practice?

Table 1: Scoring Schema for the Relative Strengths of Population, Exposure and Outcome Measures

Criterion[39]	Score	Assessment
Comparability of exposed and control groups	3	Controlled for age, sex, and SES or presence of other point or significant area contaminant sources, occupational exposure, and or other characteristics
	2	Controlled for age, sex, and SES or any other specific and relevant confounding factor.
	1	Controlling for one or two of any of the relevant confounding factors
Exposure assessment	3	Concentration and duration of exposure measured and modelled (modelled to identify incineration as the key source of exposure)
	2	Concentration of exposure measured only using biological samples (urine, blood)
	1	Concentrations of exposure using a proxy measure (environmental concentrations, modelled environmental concentrations, distance from incinerator
Outcome assessment	3	Standardized criteria and assessment for each health effect (registry)
	2	Medical diagnosis
	1	Self-reported (survey)

The final step of the literature collection was to critically appraise each relevant study to determine the extent to which it has achieved its stated study goals. The method for

[39] Scoring for study design was not used. There was only one case control study.

critically assessing each epidemiological study follows.

Critical Appraisal of Each Publication (Summary list used)

Critical appraisal is the process by which published literature is assessed to determine the extent to which the described goals of the study are achieved (Cochrane Collaboration Handbook). Each study should address a number of issues, such as:

- What is the study design?
- What is the population included for study? Is it a sample? How was the sample obtained?
- What is the exposure metric? How accurately does it reflect "true" exposure? Is it direct, individual, grouped, modelled from other data, or a proxy measure?
- How accurate and reliable are the outcome measures?
- How valid are the outcome measures as a reflection of biological relevance?
- How were the data analyzed? Are the analytic methods relevant to the methods of the study?
- How well have confounding variables been taken in to account?
- Does the analysis consider interactions (effect modification)?
- What inferences are made based on the results? Are they appropriate?
- Have alternative hypotheses been considered in the conclusions?
- Have issues of causality been addressed?

Table 2 shows an example of this information in a matrix format.

Table 2: Matrix for Interpretation and Assessment of Epidemiologic Studies

Epidemiological Study Critical Evaluation Form	
Author(s):	
Title:	
Year:	
Reference:	
Criteria	
Peer reviewed:	
Type of study (meta-analysis, cohort, case-control, cross-sectional, *etc.*):	
Population(s) studied:	
Case identification/definition:	
Sample size:	
Stratification (age, sex, *etc.*):	
Control identification/definition:	
Sample size:	
Stratification (age, sex, *etc.*):	
Group selection method:	
Outcome(s) studied:	
Data source format (*e.g.*, questionnaire, medical records, *etc.*):	
Exposure definition:	
Exposure medium	
Exposure measurement:	
Duration of exposure applicable to measurement (*i.e.*, acute, chronic):	
Toxicological/biological relevance of exposure measurement:	
Adjustments:	
Exposure levels:	
Interaction assessment:	
Results:	
(RR, OR, CI and relevant tables with dose response, *etc.*)	

Epidemiological Study Critical Evaluation Form

CI significant?	
Dose response presence/absence:	
Statistical analysis:	
Procedures/tests:	
Statistical significance:	
Significant findings:	
Non-significant findings:	
Biases identified by the authors:	
Assumptions/limitations of the study:	
Conclusions by authors:	
Comments/conclusions by reviewer:	

Each publication was abstracted in a matrix format shown above. The completed matrices are presented in ***Appendix III.*** This enables abstraction of more detailed information to assess the entire document in summary form. Specifically, the characteristics of the study, exposure measures, outcome measures, data analysis, results, conclusions and inferences were included in the abstract, including quantitative data such as relative risk, odds ratio, evidence of dose response, etc. Thus, each summary of a publication provided an indication of the extent to which the stated aims of the study were realized.

As much information as possible was abstracted and analyzed so as to allow examination of human health effects associated with municipal waste incineration with respect to the epidemiological literature. Studies that included information on patterns of exposure, relative risk, and attributable risk of disease were most useful for this purpose. While other considerations play a role in determining guidelines, this review only focuses on the assessment of the relevant epidemiological literature.

The studies which were accepted as high quality for consideration in the formation of an opinion on the relationship between municipal waste incineration and human health effects were those that studied large populations and considered large numbers of cases drawn from population-based medical registries.

Studies that rated medium to high (> 2 as an average out of a maximum of 3) for 3 categories of methods, exposure and outcome measures were considered. Because it is not helpful to include evidence for which there is a high risk of bias in a review, even if there is no better evidence, only the strongest studies were considered for the discussion on the health effects from municipal waste incinerators.

Appendix III: Critical assessment, Scoring of Studies and Interpretation of the Epidemiologic Review

Appendix III: Critical Assessment, Scoring of Studies and Interpretation of the Epidemiologic Review

Summary of Scoring for Critical Appraisals

Each primary publication that was identified by a systematic search was critically appraised. The purpose of the critical appraisal was to assess the relevance of the individual study and establish a confidence in the author's conclusions and recommendations. This is in line with the objectives of a systematic review outlined in the Cochrane Collaboration Handbook discussed in the methods section and Appendix I.

If the article scored at least 2/3 for each criterion (1. study population/control; 2. exposure measure; and 3. effect measure) it was considered sufficiently robust to include in a weight-of-evidence assessment on the health effects of municipal waste incinerators. None of the studies identified in this systematic review of the literature met this criterion. The assessment patterns are shown below.

Characteristic scored	***SCORES***			
	3	***2***	***1***	***NA***
Population	7	0	1	
Exposure	13	0	1	
Outcome	14	0	0	

PATTERNS

SCORES	***No.***	***Comment***
3,1,3	5	Five studies were rated for defining the population well and accounting for some age, sex and other important relevant factors in the analysis, as well as having a well-defined outcome and reasonable (proxy) measure of exposure.
3,1,1	1	One study was rated high for study group definition, but not for study exposure or outcome measure.
2 1 3	6	The majority of studies have middling to low level definition of population and exposure. Outcome was generally well defined.
2,1,2	1	One study was middling to low on all three scores.
NA	1	One study was a case verification. The study whose cases were being verified was 3,1,3 (Elliot el al. 1996). The outcome is not relevant for the exposure posited, however.

Reviews 3 Conclusions discussed in text of report.

*Study design/population, exposure, outcome – each measured on a score of 1,2,3 from lower quality to higher quality as per criteria.

Most of the studies rated at least 2/3 (N=11) on the first criterion (study population/control). A score of 2/3 indicates that the study corrected for relevant confounding factors such as age, sex, and socioeconomic status or other relevant confounders appropriate to the outcome studied. It is important to control for these factors in order to minimize distortion of the measurement of the relationship between exposure and outcome. Five studies had well defined populations such that they rated the highest score of 3. However, control for one critical factor is generally unaccounted for – the presence of other significant point sources of contaminant in close proximity to the incinerator and to the comparison populations. Often incinerators are located in industrial areas where there may be many sources of a variety of contaminants. If a study found an association between proximity to the incinerator and an effect it may that there are other potential influences on the outcome or that the exposure originated from other sources. Another important confounder that was rarely accounted for was occupational exposures. Many occupations have exposures to harmful chemicals with similar outcomes measured. Much of our understanding of human effects of contaminants comes from high exposures in an occupational setting. Thus, occupational exposures of parents in studies of birth characteristics are an important confounding factor.

The second criterion (measure of exposure) was consistently scored low (1/3) for all of the studies. The best measure of exposure when assessing the impact of a point source is through a combination of modeling and measured environmental concentrations specific to incinerator emissions. The modeled values predict how much of the exposure can be attributed to the incinerator and the measured value tells you how much of the compound actually made it into the environment and is a surrogate for personal exposure. Most of the studies used the distance to the incinerator as a proxy of exposure. Thee chemicals of interest have sources and routes of exposure not unique to incinerators (*e.g.,* dioxins, furans, metals).

The biomonitoring studies use biological measurements as a proxy of exposure, or as an outcome measure. No significant information arose from any of the studies to indicate unequivocally that incineration emissions are a major source of exposure or a potential cause of the outcome measured.

The third criterion (outcome measure) consistently scored high. Many studies received a 3/3 in outcome measure because of their use of medical registries. Registries are considered highly reliable sources of effects in populations. The biomonitoring studies received high scores because they used a biological measurement as their measure of effect. The studies reviewed used blood or milk as the outcome measure in the study and a surrogate for exposure. However, it is important to understand the limitations of

biomonitoring studies. Without an understanding of sources, routes of exposure, pharmacokinetics of the contaminant, and the toxicological outcome of the tissue levels of the contaminant, exposure biomonitoring is not necessarily a good measure of health effects of municipal waste incinerators.

The types of compounds that are associated with municipal waste incinerators are the same as those created with the combustion of general organic material (PAHs, particulate matter, metals, dioxins/furans, mercury, etc.). The general public is exposed to the combustion by-products and the same kinds of compounds from many sources. Examples of activities that create combustion by-products are forest fires, household fires, industrial emissions, coal fire generating plants, and cars/truck exhaust. Thus, the presence of these compounds in biological tissues is not necessarily a proxy of exposure to incineration by-products. Additional information is required to assess the contribution of each source of these compounds to a person's total exposure.

Three review articles were also reviewed. Rushton (2003) reviewed 48 references on multiple forms of waste management, including incineration. Hu and Shy (2001)[40] reviewed 28 references on epidemiological studies (including waste workers) on the health effects of waste incinerators. Francini et al. (2004) reviewed 72 references.

All three reviews are a summary of the literature; the authors do not present a critical review of the studies. Rushton (2003) and Hu and Shy (2001) note that there are inconsistent results for cancer and reproductive outcomes. Francini et al. (2004) concludes that many studies show an association between incinerators and various cancer endpoints and birth defects. These three reviews note that very few studies find an effect between incinerators and respiratory effects. All reviewers note that there may be health effects from the incinerators, but these have not been demonstrated convincingly.

The review publications have some common conclusions in summarizing their collected literature on the health effects of incinerators. All three review articles note the significant limitations in the studies; in particular: the fact that the majority of the studies occurred in areas around old technology incinerators; most studies use proxy measures of exposure to the incinerator (for example, distance of home to the incinerator); critical confounding factors are rarely considered (for example, occupational exposures; SES; smoking status; other source of exposure in the vicinity; movement in and out of study area; latency of effects). They all call for improved measures of exposures and effects. None of the review publications analyzed for publication bias, the tendency for studies with positive results to be published in preference to those that do not.

The three review papers covering more than 100 publications before 2005, do not offer any information that differs from the current evaluation of recent literature. All primary

40 This article was not available electronically or through interlibrary loan. Secondary sources and the abstract were used to summarize the authors' conclusions and recommendations.

research studies provide some information, as discussed below. Taken together, the studies do not provide enough information to infer that there is or there is not any coherent and consistent outcome *associated* with incineration.

Summary Table of Results of Critical Appraisal of Peer Reviewed Studies of Incinerator Health Effects 2000-2007

Author / Reference	Design / Population details	Outcome	Score*			Results
Cordier, S; Chevrier, C; Robert-Gnansia, E; Lorente, C; Brula, P; Hours, M (2004).Risk of congenital anomalies in the vicinity of municipal solid waste incinerators .Occupational and Environmental Medicine Vol. 61, no. 1, pp. 8-15.	Ecological. [population based]	**Congenital anomalies**	3	1	3	High road traffic volumes (RR=1.39, 95% CI 1.11, 1.74) and family income level (RR=1.62, 95% CI 1.25, 2.11) were significantly associated with increased risk of "other" category of congenital anomalies. **Negative study for Incinerator emissions**
Drummer, T. J., H. O. Dickinson, L. Parker (2003). Adverse pregnancy outcomes around incinerators and crematoriums in Cumbria, north west England, 1956-93. Journal of Epidemiology & Community Health 57(6): 456-61.	Ecological. [population based]	Birth characteristics of women in key areas plus **Congenital anomalies**	3	1	3	Risk of lethal congenital anomaly was significantly higher ($p<0.01$) among those living closer to incinerators. Significantly increased risk was seen in 2 sub-groups: heart defects and neural tube defects, specifically spina bifida. Lethal congenital anomaly OR=1.10 (95%CI: 1.03, 1.19) All neural tube defects OR=1.13 (95%CI: 1.04,1.23) Spina bifida OR=1.17 (95%CI: 1.07, 1.28) Heart defects OR=1.12 (95%CI: 1.03 to 1.22) **Positive study for lethal and neural and cardiac anomalies.**

Author / Reference	Design / Population details	Outcome	Score*			Results
Lin, C. M., C. Y. Li, et al. (2006). Birth outcomes of infants born in areas with elevated ambient exposure to incinerator generated PCDD/Fs. Environment International 32(5): 624-9.	Ecological [population based]	Birth characteristics of women in key areas: **Congenital anomalies**; birth weight; preterm birth; gender of child	3	1	3	No significant association between exposure and described outcomes of birth weight, gestation (weeks) or gender of child. The OR of preterm birth for an exposure of 0.03–0.05 and >0.05 pg TEQ/m3 rose by 12% and 22%, respectively, in 1997 and had a tendency of dose–response relationship (p-value for trend test=0.07) **Negative study**
Viel JF, Arveux P, Baverel J, Cahn JY, 2000. Soft-tissue sarcoma and non-Hodgkin's lymphoma clusters around a municipal solid waste incinerator with high dioxin emission levels. American Journal of Epidemiology. 152(1), 13-19.	Spatial distribution analysis [ecological study]	**Soft tissue sarcoma and** **Non Hodgkin's lymphoma**	3	1	3	Significant cluster effect (spatial clustering) seen in Besançon – where the incinerator is located – for both outcomes at the p=0.05 level. **Positive study for NHL**
Floret N, Mauny F, Challier B, Arveux P, Cahn JY, Viel JF, 2003. Dioxin emissions from a solid waste incinerator and risk of Non-Hodgkin's lymphoma. Epidemiology. Jul;14(4): 392-8.	Case control using registry cases and population controls.	**Non Hodgkin's lymphoma**	3	1	3	**High exposures only had a significant association.** **TABLE 2.** Association of Non-Hodgkin Lymphoma with Dioxin Exposure Categories,* City of Besançon, France, 1980–1995 **Dioxin Exposure NHL Cases Controls OR (95% CI)** Very low† 42 441 1.0 Low 91 952 1.0 (0.7–1.5) Intermediate 58 681 0.9 (0.6–1.4) **High 31 146 *2.3 (1.4–3.8)***

						Positive study for NHL at highest exposure level

Author / Reference	Design / Population details	Outcome	Score*			Results
Elliot, P., Eaton, N., Shaddick, G., and Carter, Cancer incidence near municipal solid waste incinerators in Great Britain. Part 2: histopathological and case-note review of primary liver cancer cases R. British Journal of Cancer (2000) 82(5), 1103–1106	Cross sectional chart review to confirm diagnosis of each case identified in a previous study using cancer registry data	**Liver Cancer** medical records	Schema not applicable to this. It is applicable to Elliot 1996, not included. It would be 3,1,3			Confirmed results of excess of liver cancer around incinerations as reported in Elliot 1996 (1996 study is 3,1, 3). If this confirms, then can be considered a 3,1,3 **Positive study confirmed for liver cancer.**
Miyake, Y., A. Yura, et al. (2005). Relationship between distance of schools from the nearest municipal waste incineration plant and child health in Japan. European Journal of Epidemiology 20(12): 1023-9.	Cross sectional, ecological	Allergic disorders, including wheeze, atopic dermatitis, allergic rhinitis, headache, stomach ache, and fatigue	3	1	1	Decreases in the distance of schools from the nearest municipal waste incineration plant were independently associated with an increased prevalence of wheeze, headache, stomach ache, and fatigue (adjusted odds ratios [95% confidence intervals] for shortest vs. longest (reference) distance categories = 1.08 [1.01– 1.15], 1.05 [1.00–1.11], 1.06 [1.01–1.11], and 1.12 [1.08–1.17], respectively). **Positive for non specific diagnosis** **Negative for specific diagnosis**
Tajimi, M., R. Uehara, et al. (2005). "Correlation coefficients between the dioxin levels in mother's milk and the distances to the nearest waste incinerator which was the largest source of dioxins from each mother's place of residence in Tokyo, Japan."	Cross sectional,	Dioxin concentration in breast milk sample collected at 30 days post-delivery.	2	1	3	Age & parity were significantly associated with dioxin levels (at alpha=0.05 level). (This is expected). Not significantly associated: weight, height, smoking status, consumption of vegetables from home garden, fish consumption and distance to any kind of incinerator. **Negative for incinerator exposure**

Chemosphere 61(9): 1256-62.						**impact.**

Author / Reference	Design / Population details	Outcome	Score*			Results
Tango, T., T. Fujita, et al. (2004). Risk of adverse reproductive outcomes associated with proximity to municipal solid waste incinerators with high dioxin emission levels in Japan. Journal of Epidemiology 14(3): 83-93.	Cross sectional Study area = 225,215 live births, 3,387 fetal deaths, 835 infant deaths Study region = 451,041 live births, 6,728 fetal deaths, 1,644 infant deaths	Ratio of female:male live births, low birth weight, infant deaths, infant deaths due to **congenital malformations**, early neonatal Deaths (<1 week of age), early neonatal deaths due to congenital malformations, spontaneous fetal deaths, and spontaneous fetal Deaths with to congenital malformations.	2	1	3	SMR analysis. Small, but significant, "peak-decline" risk for infant deaths and infant deaths with all congenital malformations – indicates a dose-response relationship between these 2 outcomes and exposure – the risk reaches a max level at a certain distance and then declines immediately after. This effect was not seen in analysis of SMR by distance in km – only in the analysis by Tango's Conditional analysis. All other outcomes were not significantly associated with distance from incinerators and did not show a "peak-decline" trend effect. **Inconclusive or negative influence by distance**
Reis, M. F., Sampaio C, et al. (2007). Human exposure to heavy metals in the vicinity of Portuguese solid waste incinerators--Part 2: biomonitoring lead in maternal and umbilical cord blood. International Journal of Hygiene & Environmental Health 210(3-4): 447-454.	Cross sectional Healthy women, non-occupationally exposed to heavy metals, primiparous and/or breast-feeding their first child or at least 3 years after breast-feeding their last child living at current residence for over 1 year. Ecological	Pb concentration in maternal and umbilical cord blood	2	1	3	Pb in maternal blood was significantly higher among exposed in Lisbon for T1 and T3. Significantly higher in controls at T_0. Pb in umbilical cord blood was significantly higher among exposed in Lisbon for T1, significantly higher in controls in T_0. For all other survey cycles for both locations, no significant differences were observed **Negative study for incinerator impact**

	exposure					

Author / Reference	Design / Population details	Outcome	Score*			Results
Reis, M.F. et al., Determinants of dioxins and furans in blood of non-occupationally exposed populations living near Portuguese solid waste incinerators. Chemosphere(2007), doi:10.1016/j.chemosphere.2006.05.102	Case control Cross sectional sampling Ecological exposure (exposed and unexposed populations by a priori definition)	Dioxin (PCDDs and PCDFs) concentration in blood	2	1	3	Individuals from Lisbon show higher median PCDD/F levels, likely to be better explained by more highly polluted areas in Lisbon than by eventual differences in dietary habits of the studied groups. Lack of significant findings for exposure (proximity) and blood dioxin levels suggests that control methods at the source are functioning properly. **Negative study for incinerator impact**
Reis, M. F.,Sampaio C. et al. (2007). 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. International Journal of Hygiene & Environmental Health 210(3-4): 439-46.	Cross sectional Ecological exposure (exposed and unexposed populations by distance a priori definition	Pb, Cd, Hg concentration in blood	2	1	3	Significant difference between exposed & controls in Lisbon at T0 for Hg ($P<0.05$), T1 & T2 for Pb ($p<0.05$) Significant difference between exposed & controls in Madeira at T2 for Cd and Hg ($p<0.05$) No significant difference in age & gender, or the other survey cycles. **Negative study for incinerator impact**

Author / Reference	Design / Population details	Outcome	Score*			Results
Reis, M. F., Sampaio C, et al. (2007). 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. International Journal of Hygiene & Environmental Health 210(3-4): 455-9.	Healthy children, aged between 1 and 6 years, non-twin, born from a normal pregnancy, with birth weight higher than 2500 g, without previous known environmental lead exposure, and living in the study area for over 1 year	Pb concentration in blood	2	1	3	Pb in blood was significantly higher among exposed in Lisbon for T0. Significantly higher in controls in T_1. Pb in blood was significantly higher among exposed in Madeira for T_1 No significant differences between exposed and controls in Madeira for T_0 **Possible impact for lead, need to know air and soil levels, other sources of exposure, etc.**
Leem, J. H., Y. C. Hong, et al. (2003). Health survey on workers and residents near the municipal waste and industrial waste incinerators in Korea. Industrial Health 41(3): 181-8.	Cross sectional Workers employed at incinerators and residents lived within 1.5 Km from MSW for more than 1 year.	Dioxin concentration in blood	2	1	2	**No significant differences between workers and residents exposed to MSW incinerators, for 18 types of PCDD/DF congeners at the p=0.05 level. Study is too small to make any firm conclusion** Mean concentrations of biomarkers in blood significantly greater among those living close to industrial waste incinerators rather than MSW incinerators: Body burden of dioxin (ng TEQ/kg bw) $p < .01$ daily intake of dioxin (pg I-TEQ/kg bw/day) $p < .01$ MDA (mol/mol creatinine) $p < .01$ 8-OH-dG (g/g creatinine) $p > .01$

						Inconclusive, too small a study

Interpretation of the Recent Literature on the Health Effects from Municipal Waste Incinerators

In summary, the recent epidemiologic literature relating health effects in communities close to municipal incinerators is limited in quantity, scope, and consistent methodological quality. Any health effects postulated to be related to incinerator emissions must be coherent with the exposures from incinerators, and the majority of studies do not document exposure well. There are additional challenges in studying populations around incinerators: populations around incinerators are limited in number and the outcomes of interest may be difficult to document from readily available population data (birth defects, birth weight, and cancer). This limits power to detect differences of low frequency events – the lower the frequency, the larger the population required to find statistical changes from baseline. On the other hand, survey data may be limited by biased and unsystematic reporting, while biomonitoring studies do not measure exposures uniquely attributable to incinerator emissions. Epidemiology appears to have intrinsic limits in its ability to attribute health effects to exposures measures in environmental settings. Hence, current studies do not support or reject the notion that incinerators cause empirically measurable adverse health outcomes.

Appendix IV: Abstracts, Database Source, and Print source of Relevant Studies Identified in Literature Search

Appendix IV: Abstracts, Database Source, and Print source of Relevant Studies Identified in Literature Search

#	Abstracted?	Database	Included in previous 4A report? (Y/N)	Available on-line? (Y/N)	Article citation	Abstract (If available)
1	Y	EnvPoll	N	Y	Cordier, S; Chevrier, C; Robert-Gnansia, E; Lorente, C; Brula, P; Hours, M (2004). "Risk of congenital anomalies in the vicinity of municipal solid waste incinerators." Occupational and Environmental Medicine Vol. 61, no. 1, pp. 8-15.	Background: Although municipal solid waste incineration (MSWI) has contributed to increase the overall environmental load of particulate matter containing dioxins and metals, evidence of health consequences to populations is sparse. Aims: To assess at a regional level (in southeast France) the impact of these emissions on birth defect rates. Methods: Communities with fewer than 50 000 inhabitants surrounding the 70 incinerators that operated at least one year from 1988 to 1997 were studied. Each exposed community (n = 194) was assigned an exposure index estimated from a Gaussian plume model. Poisson models and a reference population of the 2678 unexposed communities in the region were used to calculate relative risks for congenital malformations, adjusted for year of birth, maternal age, department of birth, population density, average family income, and when available, local road traffic. Results: The rate of congenital anomalies was not significantly higher in exposed compared with unexposed communities. Some subgroups of major anomalies, specifically facial clefts and renal dysplasia, were more frequent in the exposed communities. Among exposed communities, a dose-response trend of risk with increasing exposure was observed for obstructive uropathies. Risks of cardiac anomalies, obstructive uropathies, and skin anomalies increased linearly with road traffic density.
2	Y	MedLine	N	Y	Dummer, T. J., H. O. Dickinson, et al. (2003). "Adverse pregnancy outcomes around incinerators and crematoriums in Cumbria, north west England, 1956-93." Journal of Epidemiology & Community Health 57(6): 456-61.	STUDY OBJECTIVE: To investigate the risk of stillbirth, neonatal death, and lethal congenital anomaly among babies of mothers living close to incinerators and crematoriums in Cumbria, north west England, 1956-93. DESIGN: Retrospective cohort study. Logistic regression was used to investigate the risk of each outcome in relation to proximity at birth to incinerators and crematoriums, adjusting for social class, year of birth, birth order, and multiple births. Continuous odds ratios for trend with proximity to sites were estimated. SETTING: All 3234 stillbirths, 2663 neonatal deaths, and 1569 lethal congenital anomalies among the 244 758 births to mothers living in Cumbria, 1956-1993. Main results: After adjustment for social class, year of birth, birth order, and multiple births, there was an increased risk of lethal congenital anomaly, in particular spina bifida (odds ratio 1.17, 95% CI: 1.07 to 1.28) and heart defects (odds ratio 1.12, 95% CI: 1.03 to 1.22) around incinerators and an increased risk of stillbirth (odds ratio 1.04, 95% CI: 1.01 to 1.07) and anencephalus (odds ratio 1.05, 95% CI: 1.00 to 1.10) around crematoriums. CONCLUSIONS: The authors cannot infer a causal effect from the statistical associations reported in this study. However, as there are few published studies with which to compare our results, the risk of spina bifida, heart defects, stillbirth, and anencephalus in relation to proximity to incinerators and crematoriums should be investigated further, in particular

						because of the increased use of incineration as a method of waste disposal.
3	Y	MedLine	Y	Y	Elliott, P., N. Eaton, et al. (2000). "Cancer incidence near municipal solid waste incinerators in Great Britain. Part 2: histopathological and case-note review of primary liver cancer cases." British Journal of Cancer 82(5): 1103-6.	We reported previously a 37% excess risk of liver cancer within 1 km of municipal incinerators. Of 119/235 (51%) cases reviewed, primary liver cancer was confirmed in 66 (55%) with 21 (18%) definite secondary cancers. The proportions of true primaries ranging between 55% and 82% (i.e. excluding secondary cancers) give revised estimates of between 0.53 and 0.78 excess cases per 10(5) per year within 1 km.
4	Y	MedLine	Y	Y	Floret et al (2003) "Dioxin Emissions from a Solid Waste Incinerator and Risk of Non-Hodgkin Lymphoma." Epidemiology. 14(4):392-398.	Background: It is not clear whether low environmental doses of dioxin affect the general population. We previously detected a cluster of patients with non-Hodgkin lymphoma around a French municipal solid waste incinerator with high dioxin emissions. To explore the environmental route suggested by these findings, we carried out a population-based case-control study in the same area. Methods: We compared 222 incident cases of non-Hodgkin lymphoma diagnosed between 1980 and 1995 and controls randomly selected from the 1990 population census, using a 10-to-1 match. Dioxin ground-level concentrations were modeled with a second-generation Gaussian-type dispersion model, yielding four dioxin exposure categories. The latter were linked to individual places of residence, using Geographic Information System technology. Results: The risk of developing non-Hodgkin lymphoma was 2.3 times higher (95% confidence interval = 1.4-3.8) among individuals living in the area with the highest dioxin concentration than among those living in the area with the lowest dioxin concentration. No increased risk was found for the intermediate dioxin exposure categories. Adjustment for a wide range of socioeconomic characteristics at the block group level did not alter the results. Conclusion: Although emissions from incinerators are usually not regarded as an important source of exposure to dioxins compared with other background sources, our findings support the hypothesis that environmental dioxins increase the risk of non-Hodgkin lymphoma among the population living in the vicinity of a municipal solid waste incinerator.

5	Not abstracted - Review article, included in main report	MedLine	N	Y	Franchini, M., M. Rial, et al. (2004). "Health effects of exposure to waste incinerator emissions:a review of epidemiological studies." Annali Dell'Istituto Superiore di Sanita 40(1): 101-15.	This review evaluates the epidemiological literature on health effects in relation to incineration facilities. Several adverse health effects have been reported. Significant exposure-disease associations are reported by two thirds of the papers focusing on cancer (lung and larynx cancer, non-Hodgkin's lymphoma). Positive associations were found for congenital malformations and residence near incinerators. Exposure to PCB and heavy metals were associated with several health outcomes and in particular with reduction of thyroid hormones. Findings on non-carcinogen pathologies are inconclusive. Effect of biases and confounding factors must be considered in the explanation of findings. Methodological problems and insufficient exposure information generate difficulties on study results. Research needs include a better definition of exposure in qualitative and quantitative terms in particular by developing the use of biomarkers and by implementing environmental measurements. [References: 72]
6	N - article not available	MedLine	N	N	Hu, S. W. and C. M. Shy (2001). "Health effects of waste incineration: a review of epidemiologic studies." Journal of the Air & Waste Management Association 51(7): 1100-9.	There is an increasing trend toward using incineration to solve the problem of waste management; thus, there are concerns about the potential health impact of waste incineration. A critical review of epidemiologic studies will enhance understanding of the potential health effects of waste incineration and will provide important information regarding what needs to be investigated further. This study reviews the epidemiologic research on the potential health impact of waste incineration. Previous studies are discussed and presented according to their study population, incinerator workers or community residents, and health end points. Several studies showed significant associations between waste incineration and lower male-to-female ratio, twinning, lung cancer, laryngeal cancer, ischemic heart disease, urinary mutagens and promutagens, or blood levels of certain organic compounds and heavy metals. Other studies found no significant effects on respiratory symptoms, pulmonary function, twinning, cleft lip and palate, lung cancer, laryngeal cancer, or esophageal cancer. In conclusion, these epidemiologic studies consistently observed higher body levels of some organic chemicals and heavy metals, and no effects on respiratory symptoms or pulmonary function. The findings for cancer and reproductive outcomes were inconsistent. More hypothesis-testing epidemiologic studies are needed to investigate the potential health effects of waste incineration on incinerator workers and community residents. [References: 28]
7	Y	MedLine	N	Y	Leem, J. H., Y. C. Hong, et al. (2003). "Health survey on workers and residents near the municipal waste and industrial waste incinerators in Korea." Industrial Health 41(3): 181-8.	Hazardous substances, such as polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) also have been detected in Municipal Solid Waste (MSW) and industrial waste incinerators in Korea. In this study, we estimated the exposure status of these hazardous substances and their heath effects in workers and residents near the MSW incinerators and residents near the industrial waste incinerators. We interviewed 13 workers and 16 residents from the area around the two MSW incinerators, and further 10 residents from the area around one industrial waste incinerator, which is suspected to emit higher hazardous substances. During the interview we collected information including sociodemographic information, personal habits, work history, detailed gynecologic and other medical history. Blood samples from 45 subjects were also collected for analysis of PCDDs and PCDFs, which were analyzed by HRGC-HRMS (High Resolution Gas Chromatography-High Resolution Mass Spectrometer). In addition to a questionnaire survey, urinary concentrations of 8-hydroxydeoxyguanosine (8-OH-dG) and malondialdehyde (MDA) were measured as oxidative injury biomarkers. Urinary concentrations of 8-OH-dG were determined by in vitro ELISA (JAICA, Fukuroi, Japan). MDA were determined by HPLC

							using adduct with TBA (thiobarbituric acid). The PCDD/F concentrations in residents from the area around industrial waste incinerator were higher than those in workers and residents from the area around MSW incinerator. The average toxic equivalency (TEQ) concentrations of PCDD/Fs in residents from the area around industrial waste incinerator were 53.4 pg I-TEQs/g lipid. The average TEQ concentrations of PCDD/Fs in workers and residents near MSW incinerator were 12.2 pg I-TEQs/g lipid. Estimated daily intake (EDI) of each person was calculated, and the EDI of all workers and residents near MSW incinerator were within the tolerable daily intake range. But for only 30% of 10 people near the industrial waste incinerator were the EDI within the tolerable daily intake range (1-4 pg I-TEQ/kg bw/day) suggested by WHO (1997). The oxidative stress of residents near the industrial waste incinerator was higher than that in workers and residents from the area around MSW incinerator. This oxidative stress may have been caused by hazardous substances, such as PCDD/Fs emitted by incinerators. The residents from the area around industrial waste incinerator were exposed to hazardous substances such as PCDD/ Fs. Proper protection strategies against these hazardous chemicals are needed.
8	Y		MedLine	N		Y	Lin, C. M., C. Y. Li, et al. (2006). "Birth outcomes of infants born in areas with elevated ambient exposure to incinerator generated PCDD/Fs." Environment International 32(5): 624-9.	The purpose of this study was to determine if elevated ambient exposure to incinerator generated polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) may affect birth outcomes of exposed infants born in Taipei metropolitan areas, Taiwan. The relationships between exposure to elevated PCDD/Fs concentration and various birth outcomes including birth weight, gestational age, and proportion of females were cross-sectionally assessed in 1991 (one year before the incinerator started to operate) and 1997 (five years later), respectively. We used the US EPA Industrial Source Complex Model-Sort Term modeling technique to determine the ambient PCDD/Fs concentrations in the study areas, in which 40 districts with annual averaged PCDD/Fs exposure of > or = 0.03 pg TEQ/m3 were considered as the exposed areas and another 40 districts with an estimated concentration of zero were randomly selected as reference areas. Information on birth outcomes was retrieved from the Taiwan's Birth Registry. A total of 6697 and 6282 neonates were included in the analysis for 1991 and 1997, respectively. After controlling for potential confounders, the results showed that the odds ratios (ORs) of low birth weight (< 2500 g) for higher exposures were 0.94 (> 0.05 pg TEQ/m3) and 091 (0.03-0.05 pg TEQ/m3) in 1991 and were 1.07 (> 0.05 pg TEQ/m3) and 1.06 (0.03-0.05 pg TEQ/m3) in 1997. The corresponding ORs were 1.05/0.86 (1991) and 1.12/1.22 (1997) for preterm (< 37 completed weeks of gestation), as well as 0.95/1.00 (1991) and 0.95/0.90 (1997) for female births. The above ORs were all close to unity and were statistically insignificant. When birth weight was analyzed as a continuous variable, the difference in mean birth weight between exposed group (> 0.03 pg TEQ/m3) and reference group decreased from 3.02 g in 1991 to -5.87 g in 1997. Analysis of continuous data also showed that the mean difference in gestational age between exposed and reference areas decreased from 0.05 weeks in 1991 to -0.09 week ($p<0.05$) in 1997. This study tends to conclude that the incinerator generated dioxin poses little effects on birth weight and female birth, but might pose small effects on gestational age. If the observed adverse effects turn out to be real, the measures now taken for improvement of abatement of waste gases seem to be a wise thing to do.

9	Y	MedLine	N	Y	Miyake, Y., A. Yura, et al. (2005). "Relationship between distance of schools from the nearest municipal waste incineration plant and child health in Japan." European Journal of Epidemiology 20(12): 1023-9.	In Japan, the main source of dioxins is incinerators. This study examined the relationship between the distance of schools from municipal waste incineration plants and the prevalence of allergic disorders and general symptoms in Japanese children. Study subjects were 450,807 elementary school children aged 6-12 years who attended 996 public elementary schools in Osaka Prefecture in Japan. Parents of school children completed a questionnaire that included items about illnesses and symptoms in the study child. Distance of each of the public elementary schools from all of the 37 municipal waste incineration plants in Osaka Prefecture was measured using geographical information systems packages. Adjustment was made for grade, socioeconomic status and access to health care per municipality. Decreases in the distance of schools from the nearest municipal waste incineration plant were independently associated with an increased prevalence of wheeze, headache, stomach ache, and fatigue (adjusted odds ratios [95% confidence intervals] for shortest vs. longest distance categories =1.08 [1.01-1.15], 1.05 [1.00-1.11], 1.06 [1.01-1.11], and 1.12 [1.08-1.17], respectively). A positive association with fatigue was pronounced in schools within 4 km of the second nearest municipal waste incineration plant. There was no evident relationship between the distance of schools from such a plant and the prevalence of atopic dermatitis or allergic rhinitis. The findings suggest that proximity of schools to municipal waste incineration plants may be associated with an increased prevalence of wheeze, headache, stomach ache, and fatigue in Japanese children.
10	Y	MedLine	Y	Y	Reis, M. F., J. P. Miguel, et al. (2007). "Determinants of dioxins and furans in blood of non-occupationally exposed populations living near Portuguese solid waste incinerators." Chemosphere 67(9): S224-30.	Biomonitoring of dioxin body burden, as evaluated by PCDD/F levels in blood, has been carried out in a total of 138 adults from general population living in the vicinity of solid waste incinerators in Portugal. Measurements were performed included in cross-sectional surveys within two Environmental Health Surveillance Programs launched in response to ecotoxicological concern in relation to solid waste incinerators near Lisbon and in Madeira Island. Overall conclusion from first published results is indicative that dioxin exposure of global populations cannot be related to the emissions of these facilities, meaning that dioxin sources control seems to be effective in relation to both incinerators. Main objective of present work was to investigate potential determinants of dioxin levels in the studied populations. Findings from this investigation also suggest that incineration does not impact on dioxin blood levels of nearby residents. Follow-up of a small group of individuals (22) from Lisbon gives preliminary indication on temporal control effectiveness of the Lisbon facility. Regarding comparison between PCDD/F levels from Lisbon and Madeira communities, individuals from Lisbon show higher median PCDD/F levels, likely to be better explained by more highly polluted areas in Lisbon than by eventual differences in dietary habits of the studied groups. In fact, analysis performed on the diet of both groups (not detailed in the present study) does not show a statistically significant difference in relation to any of the most relevant foodstuffs in the context of dioxin exposure. Comparison between Lisbon and Madeira in relation to pattern of the single congeners for PCDD/Fs shows a very similar profile. The highest contributions to the PCDD/Fs toxicity came from 12378-PCDD, 23478-PCDF, Hexa-CDD, 2378-TCDD and Hexa-CDF.

11	Y	MedLine	N	Y	Reis, M. F., C. Sampaio, et al. (2007) "Human exposure to heavy metals in the vicinity of Portuguese solid waste incinerators--Part 2: biomonitoring of lead in maternal and umbilical cord blood." (2007)International Journal of Hygiene & Environmental Health. 210(3-4):447-54.	As part of environmental health surveillance programs related to solid waste incinerators located near Lisbon and on Madeira Island, human biomonitoring projects have been implemented in Portugal, some of them focused on cross-sectional surveys of heavy metals in blood. One of the general aims of these programs is to provide Portuguese data on the extent and pattern of human exposure to the pollutants potentially released in the stack gases from the incinerators, namely heavy metals. The present investigation reports information specifically on blood lead levels of newborn-mother pairs living in the vicinity of the incinerators under study, as well as of statistically similar participants living outside the exposed area. For Lisbon, lead levels determined at the baseline period (T0), as well as three subsequent evaluations of potential specific impacts of the incinerator (T1, T2 and T3) are described in order to investigate spatial and temporal trends of human exposure to lead. Available data for Madeira, namely lead levels in blood from the study population before the incinerator started operation, is also described. For Lisbon, analyses showed a statistically significant decrease of lead concentrations in maternal ($p<0.001$) and umbilical cord blood ($p<0.001$) during the whole monitoring period. Practically "overt" transplacental exposure to lead was observed only in the Lisbon biomonitoring project and for some cross-sectional surveys. Baseline levels for Madeira were the lowest found in all observations already performed in both programs (maternal and umbilical cord mean lead levels of 0.4 microg/dl and 0.3 microg/dl, respectively). No statistical associations have been found between lead levels in blood and age neither for global populations from Lisbon and Madeira nor for specific groups included in the different observational periods.
12	Y	MedLine	N	Y	Reis, M. F., C. Sampaio, et al. (2007). "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." International Journal of Hygiene & Environmental Health 210(3-4): 439-46.	Human exposure to heavy metals makes it necessary to monitor these elements in the human body if the objective is to relate heavy metal exposure to adverse health effects. In Portugal, biomonitoring projects on heavy metals are being carried out on people living in the vicinity of solid waste incinerators. The projects are being developed in the ambit of two environmental health surveillance programs related to solid waste incineration facilities, one near Lisbon and the other on Madeira Island, that have the main objective of guaranteeing the safeguard of public health in relation to the potential negative impact of incineration processes on human health. These programs are the only ones in the country that integrate a systematic observation of human exposure to heavy metals as determined by the respective body burden in several population groups. Therefore, they are the only ones that are currently able to provide systematic data from Portuguese regions on the extent and pattern of human exposure to this type of pollutants. The present paper is the first of a series of three prepared papers with the objective of presenting and discussing available data. It addresses exposure to lead, cadmium and mercury as determined by their levels in blood of general population adults. Results suggest the effectiveness of source control measures in relation to both incinerators under study, similarly to what has been concluded from previous studies addressing exposure to dioxins. They also show, in relation to the baseline situation, a general significant trend for reduction of exposure to all studied heavy metals. Individuals from Lisbon seem to have a significantly higher body burden of the studied metals than those living in Madeira and, in general, metal exposure in men is significantly higher than in women, with the most relevant exception being the case of higher mercury levels in women, at the baseline and for both communities. Compared with published reference values for similar conditions, blood levels of cadmium, lead, and mercury of the present investigation seem to be relatively higher, in median terms and for

						extreme values, mainly in the case of cadmium and mercury. In the case of lead the differences are not so marked.
13	Y	MedLine	N	Y	Reis, M. F., C. Sampaio, et al. (2007). "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." International Journal of Hygiene & Environmental Health 210(3-4): 455-9.	As a part of environmental health surveillance programs related to Portuguese solid waste incinerators (SWI), two biomonitoring projects have been established to investigate additional exposure to lead in children under the age of 6 years living in the vicinity of those facilities. The above-mentioned programs, being the only ones in the country that integrate systematic observations on human exposure to heavy metals, have to provide systematic data from Portuguese regions on the extent and pattern of human exposure to heavy metals, namely to lead. The present paper is the third of a series of papers prepared to accomplish that objective in regards to lead exposure as evaluated by measuring lead levels in children under the age of 6 years. Altogether, 250 children from Lisbon and 247 from Madeira Island have already been involved in the investigation. The present study evaluates spatial and temporal trends of lead exposure, based on comparisons of children's blood lead levels, either stratified by living area (exposed and control groups), or by time of exposure (T0, the baseline time, and T1, after approximately 2 years of regular operation of the facilities). The results obtained correspond to a relatively reduced number of individuals. Possibly for this reason, they are not fully conclusive in relation to whether living in the vicinity of SWI represents an additional risk of higher exposure to lead. Time trends of lead exposure as evaluated by blood lead levels in children also do not show any clear pattern. These conclusions and the fact that altogether around 3% of children from the whole group have blood lead levels >or=10 microg/dl warrant further investigation in order to clarify the contribution of incinerator emissions to the levels of lead in children and to identify alternative sources for preventive purposes, taking into consideration the relevance of even low lead exposure from a public health perspective, mainly in relation to children.
14	Not abstracted - Review article, included in main report	MedLine	Y	Y	Rushton, L. (2003). "Health hazards and waste management." British Medical Bulletin 68: 183-97.	Different methods of waste management emit a large number of substances, most in small quantities and at extremely low levels. Raised incidence of low birth weight births has been related to residence near landfill sites, as has the occurrence of various congenital malformations. There is little evidence for an association with reproductive or developmental effects with proximity to incinerators. Studies of cancer incidence and mortality in populations around landfill sites or incinerators have been equivocal, with varying results for different cancer sites. Many of these studies lack good individual exposure information and data on potential confounders, such as socio-economic status. The inherent latency of diseases and migration of populations are often ignored. Waste management workers have been shown to have increased incidence of accidents and musculoskeletal problems. The health impacts of new waste management technologies and the increasing use of recycling and composting will require assessment and monitoring. [References: 48]

15	Y	MedLine	N	Y	Tajimi, M., R. Uehara, et al. (2005). "Correlation coefficients between the dioxin levels in mother's milk and the distances to the nearest waste incinerator which was the largest source of dioxins from each mother's place of residence in Tokyo, Japan." Chemosphere 61(9): 1256-62.	BACKGROUND: To observe the relationship between the PCDD/F and Co-PCB levels in samples of human breast milk and nearby waste incinerators in Tokyo, Japan. METHODS: Breast milk was taken from 240 mothers residing in Tokyo, Japan to measure and analyze the concentrations of polychlorinated dibenzo-p-dioxins (PCDDs; 14 congeners), polychlorinated dibenzofurans (PCDFs; 15 congeners), and coplanar polychlorinated biphenyls (Co-PCBs; 12 congeners) contained in the fat. Individual milk samples (about 50 ml) were obtained from the mothers 30 days after delivery, between the months of June and September in 1999 and 2000. A map of Tokyo was used to measure the distances between each mother's place of residence and the closest public and industrial waste incinerators. RESULTS: The distances to the nearest waste incinerators bore no apparent correlations with the congeners of PCDD/Fs and Co-PCBs. The distances were also uncorrelated with the mean toxic equivalent quantities (TEQs) of PCDD/Fs (the sum of PCDDs and PCDFs), Co-PCBs, and the total PCDD/Fs and Co-PCBs. CONCLUSIONS: Although waste incinerators were the largest source of dioxins in Japan at the time of the study, the dioxins levels of mother's milk bore no apparent relationships with the distances between the mothers' domiciles and the nearest waste incinerators. In this study, several meaningful factors were not taken into account, namely, the wind direction, the level of dioxin emitted from each incinerator, the level of environmental pollution of dioxins, and the average time the mothers stayed at home each day. A full understanding of these points awaits future studies.
16	Y	MedLine	Y	Y	Tango, T., T. Fujita, et al. (2004). "Risk of adverse reproductive outcomes associated with proximity to municipal solid waste incinerators with high dioxin emission levels in Japan." Journal of Epidemiology 14(3): 83-93.	BACKGROUND: Great public concern about health effects of dioxins emitted from municipal solid waste incinerators has increased in Japan. This paper investigates the association of adverse reproductive outcomes with maternal residential proximity to municipal solid waste incinerators. METHODS: The association of adverse reproductive outcomes with mothers living within 10 km from 63 municipal solid waste incinerators with high dioxin emission levels (above 80 ng international toxic equivalents TEQ/m3) in Japan was examined. The numbers of observed cases were compared with the expected numbers calculated from national rates adjusted regionally. Observed/expected ratios were tested for decline in risk or peak-decline in risk with distance up to 10 km. RESULTS: In the study area within 10 km from the 63 municipal solid waste incinerators in 1997-1998, 225,215 live births, 3,387 fetal deaths, and 835 infant deaths were confirmed. None of the reproductive outcomes studied here showed statistically significant excess within 2 km from the incinerators. However, a statistically significant peak-decline in risk with distance from the incinerators up to 10 km was found for infant deaths (p=0.023) and infant deaths with all congenital malformations combined (p=0.047), where a "peak" is detected around 1-2 km. CONCLUSION: Our study shows a peak-decline in risk with distance from the municipal solid waste incinerators for infant deaths and infant deaths with all congenital malformations combined. However, due to the lack of detailed exposure information to dioxins around the incinerators, the observed trend in risk should be interpreted cautiously and there is a need for further investigation to accumulate good evidence regarding the reproductive health effects of waste incinerator exposure.

17	Y	MedLine	Y	Y	Viel et al (2000) "Soft-Tissue Sarcoma and Non-Hodgkin's Lymphoma Clusters around a Municipal Solid Waste Incinerator with High Dioxin Emission Levels." American Journal of Epidemiology. 152:13–1	Overall evidence from epidemiologic studies in the workplace suggests that dioxin is a human carcinogen, but whether low doses affect the general population remains to be determined. Th examined the spatial distribution of soft-tissue sarcomas and non-Hodgkin's lymphomas arour French municipal solid waste incinerator with high emission levels of dioxin (16.3 ng internatio equivalency factor/m3). Not consistently associated with dioxin exposure, Hodgkin's disease s the control cancer category. Clusters were identified from 1980 to 1995 in the area ("departem Doubs by applying a spatial scan statistic to 26 electoral wards. The most likely and highly sig clusters found were identical for soft-tissue sarcomas and non-Hodgkin's lymphomas and inclu area around the municipal solid waste incinerator; standardized incidence ratios were 1.44 (ob number of cases = 45, focused test p value = 0.004) and 1.27 (observed number of cases = 2 focused test p value = 0.00003), respectively. Conversely, Hodgkin's disease exhibited no spe spatial distribution. Confounding by socioeconomic status, urbanization, or patterns of medica seemed unlikely to explain the clusters. Although consistent, these findings should be confirm further investigation (e.g., a case-control study in which dioxins are measured in biologic tissu clusters of soft-tissue sarcoma and non-Hodgkin's lymphoma are ascribed to dioxin released b municipal solid waste incinerator.

Appendix V: References

Appendix V: References

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