BC Centre for Disease Control
An agency of the Provincial Health Services Authority

Health assessment for thermal treatment of municipal solid waste in British Columbia

Evidence review and recommendations

Final Report of the Waste to Energy Working Group

BC Environmental Health Policy Advisory Committee

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Executive Summary

While proper waste management is a benefit of modern society, it has potential for producing adverse health impacts. Waste management is a complex process involving pick up, sorting, diversion and final disposal. Effective waste management reduces exposures to biological, chemical and physical hazards and leads to employment, energy production and other benefits. It also has potential for adverse impacts on the physical, social and economic environments and ultimately on the health and well-being of populations. Unless these impacts are properly considered, there is a risk of spoiling the benefits of waste management.

Communities throughout British Columbia (BC) are receiving proposals for thermal treatment of waste streams such as municipal solid waste, wood waste and other combustibles. The BC Environmental Health Policy Advisory Committee struck a working group in June 2010 to determine how health impacts of waste management proposals should be assessed (hereafter referred to as the "Working Group"). The impetus was a number of requests for public health agencies and their staff to comment on health impacts of proposed facilities for thermal treatment of waste and production of energy. The Working Group chose to focus its assessment on municipal solid waste treatment facilities because there is a greater body of scientific evidence about its health effects and many of the general principles can be applied to any type of waste management.

This report completes the task of the Working Group. It provides a summary of what is known about health impacts of thermal treatment facilities, and unknown issues that require further study. It provides a framework for considering potential health impacts of waste management from the policy level to the operations of individual facilities. It proposes a process for health assessment that builds upon current regulatory processes, such as environmental impact assessment process, and addresses gaps where health assessment is currently inconsistent. The process is flexible and can be simple or elaborate as required. This approach to health assessment could be adapted for other health issues that involve complex technologies, multiple stakeholders and potential for environmental, social and economic impacts.

In *Section 1* we describe thermal treatment of MSW: technologies, emissions, and lifecycle considerations as relevant for health assessment. In *Section 2*, we report on a review of the evidence on health effects of thermal treatment of MSW, and lessons learned for human health risk assessment. In *Section 3*, we integrate BC current practice with international experiences of health assessment and propose a process for health assessment of waste management in BC. The appendices contain explanations of key concepts and detailed case studies.

Many of the recommendations are complementary to processes currently underway in BC regional health authorities to improve health assessment for major projects. Several health authorities have identified a need to address health impacts of resource extraction, transportation projects and changes to the built environment, and the recommendations in this report include developing health impact assessment expertise that could be accessed by health authorities for waste management and other projects. This document provides some case examples of how such expertise has been used in other jurisdictions.

Improving the health outcomes from waste management is a task that involves many levels and ministries of government, many stakeholders and community groups. Public health professionals have an important role in leading and/or critiquing health assessments, sharing content expertise, and working with multiple stakeholder groups. It is critical that we use our skills to ensure that health is assessed for each of the policy and project options considered. Only then will we be equipped to take the opportunity provided by each waste management decision to select those options that optimize health and well-being for all people in British Columbia.

Introduction

Public health practitioners are often either ill-equipped or poorly positioned to influence the proximal determinants of health.[a] Decisions that shape the physical, social and policy environments that favour health are made in ministries of government other than health, in regional policies and in official community plans. Nevertheless, public health practitioners have made major contributions in certain environmental issues, notably, the reduction of exposures to environmental toxins through their research and advocacy supporting removal of lead from gasoline, limiting the mining and use of asbestos and banning certain pesticides. In others, they are beginning to play a role, such as in planning built environments (e.g., Dannenberg et al. 2011).[52] Other issues, such as solid waste management, are just beginning to emerge as public health issues, driven in part by public concerns about the potential health risks of pollution from solid waste treatment facilities.

Solid waste management can be a highly controversial subject, conjuring unsightly images of overflowing garbage cans, toxic dumps and vermin. Considered unhealthy, waste is to be banished and disposed of in someone else's backyard. Waste management facilities sited in disadvantaged neighbourhoods can lead to real or perceived inequities in nuisance and exposures to hazards.[53] There can be little acceptance of waste as an inevitable product of modern living. Community opposition to waste facilities is often expressed through concern about health risks and both local public health practitioners and international scientific experts may be called upon to weigh in to the debate.[54] Faced with the task of presenting the evidence on potential adverse health effects of waste management projects, public health practitioners may find that the causal links between waste facilities and health effects are either not well described in the literature or that the studies are based on outdated technologies with emissions that far exceed those of today. When approaching the task of preventing adverse health effects of waste management they may find that most interventions are outside the purview of public health departments. Thus intervening effectively to ensure that the potential ill effects of waste management are minimized is a challenging task for public health practitioners.

The BC Environmental Health Policy Advisory Committee struck a working group in June 2012 to determine how health impacts of proposed changes to solid waste management should be assessed (hereafter referred to as the "Working Group"). The impetus was a number of proposed facilities for incineration of waste and production of energy. The Working Group chose to focus on municipal solid waste treatment facilities with the understanding that many of the general principles can be applied to any type of waste treatment facility.

This report summarises the work of the Working Group. In Section 1 we describe thermal treatment of MSW: technologies, emissions, and lifecycle considerations as relevant for health assessment. In Section 2, we report on a review of the evidence on health effects of thermal treatment of MSW, and lessons learned for human health risk assessment. In Section 3, we integrate BC current practice with international experiences of health assessment and propose a process for health assessment of waste management in BC.

[a] Proximal determinants of health are those determinants which act directly to influence health. They include socioeconomic environment, physical environment, host constitution and the health system. Distal determinants of health influence the proximal determinants. They include social, political, legal, cultural and economic systems.[52]

Section 1: Overview of Thermal Treatment of Municipal Solid Waste

Thermal treatment is a method of final disposal of municipal solid waste (MSW). The other major method used in Canada is waste disposal in a sanitary landfill. In British Columbia, the majority of municipal solid waste is disposed in landfills. There is only one thermal treatment plant, a mass burn incinerator that converts waste to energy in Burnaby BC. This facility is described in detail in Appendix A.

Municipal solid waste may undergo a variety of treatments prior to final disposal in order to remove usable by-products or produce energy (Figure 1). MSW may go directly from curb side pick-up to final treatment or it may be diverted to remove useful items for recycling and/or composting. Waste sorted by the householder into recyclables and compost (source segregation) is said to be 'diverted' from the waste stream. More complete removal of recyclables and combustibles occurs in mechanical biological treatment (MBT). Waste that is picked up at the curb is delivered to a central MBT plant where it is mechanically sorted and treated. Mechanical sorting removes recyclables and combustible material. Sorting may precede or follow biological treatment, depending upon the design of the MBT facility. If *unsorted* waste is biologically treated, then bio-drying is used to reduce the waste and products are disposed in thermal treatment or landfill. If sorting precedes biological treatment then biological materials usually undergo anaerobic or aerobic digestion to produce biogas and compost-like outputs. In this latter scenario, the non-organic waste is sorted into recyclables and residual and the residual is disposed in thermal treatment or landfill.

Thermal Treatment Technologies

Waste-to-energy is a term commonly used to describe mass burn incineration, the most established thermal treatment. Pyrolysis and gasification are newer forms of thermal treatment that have much shorter track records in Canada (Table 1); although both pyrolysis and gasification plants have been operating in Europe and Asia since the early 2000s (DEFRA[1] provides a detailed list of these plants). A more detailed technical review of waste-to-energy technologies and emissions is provided in a recent report commissioned by the BC Ministry of the Environment.[2] There are several commercial technologies described for pyrolysis and gasification, each with its own specifications.[1,3-5] We focus on a general overview of these technologies, rather than detail the specifications of particular commercial applications. Both untreated and treated waste can be used in each technology; however the waste stream must have sufficient caloric value to supply adequate energy output if the plant is to be economically viable.

Mass burn incineration is the technology with the longest history and remains the dominant one in use today. The waste stream is burned in large volumes and at high temperatures in the presence of oxygen to achieve full oxidation to carbon dioxide and water. Heat generated may be used for local heating or converted to electricity. Major by-products are air emissions, waste water, and solid waste, including bottom ash and scrubbers.

Pyrolysis occurs in the absence of oxygen at lower temperatures (470-700°C). Products of pyrolysis include a synthetic gas (syngas) and solid residue. The syngas is further treated for use as a liquid fuel. Solid by-products include char residues from pyrolysis, which may undergo metals recovery and/or be converted to vitrified slag pellets[b] for use in construction fill. The process of vitrifying occurs at high temperature, resulting in an inert material.

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[b] The process of vitrification occurs at high heat (e.g. >1000°C), and may produce gas which can be combusted for energy.

Gasification involves partial oxidation of MSW to produce fuel which is cleaned, then used in heat-energy co-generation. By-products include solid materials (char) from the gasification process, air pollution control scrubbers, wastewater, and air emissions.

Of the above technologies, only mass burn incineration is proven for management of large volumes of municipal solid waste. Pyrolysis and gasification technologies are under development and some pilot facilities exist, however, only limited data describing their operations are available (Table 1).[2]

***Table 1.1** Examples of pyrolysis and gasification facilities in Canada*

Manufacturer	Technology	Location	Operating Since	Waste	MSW volume
Plasco Red Deer	Pyrolysis/gasification	Red Deer, AB	Proposed	MSW	200 tonne/day
Plasco Ottawa	Pyrolysis/gasification	Ottawa, ON	January 2008, intermittent	MSW	100 tonne/day design
Enerkem	Gasification	Sherbrooke, QC	2003	Multiple feedstocks tested	Not listed
Enerkem	Gasification	Westbury, QC	January 2009 (gasifier), processing of syngas – proposed for Fall 2010	Wood waste (decommissioned electricity poles)	Not listed

Facility Emissions

Emissions from thermal treatment include air emissions, liquid effluents, and solid wastes; each described in detail in a technical report commissioned by the BC Ministry of the Environment[2] and a brief overview is provided here.

Constituents of air emissions include particulate matter, acid gases (SOx, NOx, HCl and HF), heavy metals (mercury, cadmium, tin, arsenic, nickel etc), organic compounds (dioxins and furans), and products of incomplete combustion (CO and other organic compounds).

Air emissions are either point source or fugitive emissions. Point source emissions are from a single source, such as the exhaust stack, and are usually the major source of emissions.[2] Air pollution control measures, such as scrubbers and fabric filters reduce point source emissions considerably. Fugitive emissions to air occur when air is vented from an area-based source, such as a refuse holding or sorting area. Fugitive emissions can be effectively controlled by maintaining operations at negative pressure and through other design and operations measures.

Some thermal treatment plants also generate wastewater effluent during operation; in addition to regular wastewater streams, such as runoff and sewage which can be handled in the municipal system. The main source of wastewater effluents from thermal treatment is the air pollution control system (APC). APC using wet scrubbers generates significant wastewater effluent, whereas using dry scrubbers generates a small amount of effluent. Wastewater effluent from wet scrubbers can be treated on site to render pollutant levels well below usual discharge standards; however, small amounts of heavy metals and some organics may remain. A detailed description of the constituents of wastewater effluent after treatment is found in the technical report by Stantec.[2]

Solid wastes generated by thermal treatment plants will depend on plant design and the nature of waste streams, including: wastes removed prior to combustion, bottom ash, metallic scrap, air pollution control residues, char, residues from wastewater treatment, gypsum, and loaded activated carbon. The toxicity of these wastes varies; however, in most cases the wastes generated from air and water treatment are heavily loaded with metals and contain traces of dioxins and furans that must be handled as hazardous wastes; remainder of the wastes can be disposed of in a sanitary landfill. The largest solid waste stream is the bottom ash, which is 20-25% of the original waste by weight or 5-10% by volume.[2]

Lifecycle Considerations

Thermal treatment plants operate within a system of waste production, treatment and final disposal. It is important to consider the emissions the entire system. Waste transport from the site of production to the treatment facility is one of the major sources of emissions in waste disposal. The human receptors for these emissions may differ, as different populations live along transport routes versus near the facility. Therefore both the facility emissions and the emissions from transport should be considered during environmental and human health impact assessment.

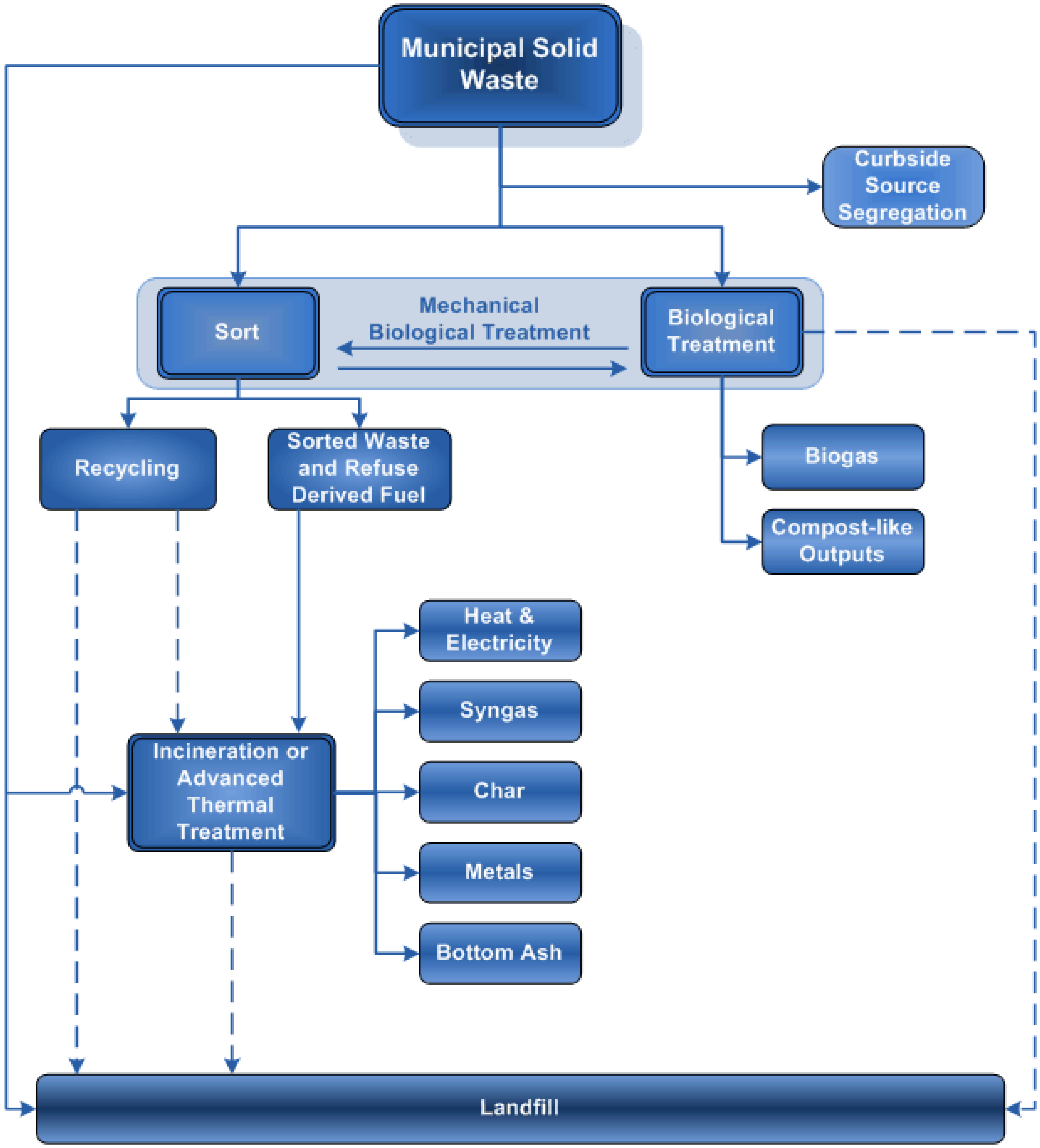

Figure 1.1 Municipal solid waste treatment options. Adapted from DEFRA.[6]

Section 2: Health Effects of Thermal Treatment of Municipal Solid Waste: a review of the evidence

Introduction

There is considerable debate regarding the health impacts of thermal treatment of municipal solid waste. The conclusions of government and scientific reviews differ, despite a common evidence base (Table 4). Authors of reviews disagree on (1) which health outcomes, if any, were associated with incineration and (2) the certainty of the evidence that incineration caused these effects.

The most conservative assessment is provided by the American National Research Council who concluded that epidemiologic evidence from older facilities may prove useful in defining an upper range of health effects beyond those that would be associated with modern facilities.[7] In contrast both the UK Department for Environment Food and Rural Affairs and Health Protection Scotland agree that given the low emissions of modern MSWI they are likely to be associated with very small health effects, if any.[8-10] The UK Committee on Carcinogenicity of Chemicals in Food, Consumer Products and Environment concludes that any increased risk of cancer near older incinerators was small and, although there are currently no concerns, the issue should be kept under review; however they did not quantify this risk.[11,12] The authors of other reviews disagree about which health outcomes have suggestive evidence to support an association with MSWI. More inclusive reviews include birth defects and types of cancer,[13] whereas less inclusive ones state that the evidence is inconclusive for all health outcomes.[7] It is common for disagreement to occur in such instances when the evidence is poor or inconsistent.

In order to make our own conclusions, we conducted a systematic review of the primary literature[c] to address the questions:

- Which, if any, health conditions are associated with exposure to emissions from thermal treatment of MSW?
- Where there is evidence of an association, what is the certainty that the health effects were caused by exposure to emissions from MSW treatment?
- How generalizable are the published findings to British Columbia context in 2012?

Methods

Literature Search

We conducted a systematic review of literature for all human health effects associated with incineration, gasification, pyrolysis, and other waste-to-energy facilities. Detailed search methodology is available upon request. Briefly, once the literature was scoped using Google Scholar and Web of Science, the entire collection of Ebsco databases, available through the UBC library, was searched. Searches were restricted to peer-reviewed journals in English and the date range was initially set at 2000-2010, although this limitation was removed and search strings rerun to ensure that no important studies were overlooked. Papers pertaining to medical waste or electronic waste were excluded. Bibliographies of most relevant articles were electronically and manually scanned (citation chaining,

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[c] Primary literature consists of the original peer-reviewed studies that form the evidence base for reviews of health effects.

snowballing) to build the library for this topic. Forward search strategies were also employed across various databases (e.g., Ebsco, Scopus, and Google Scholar).

Evidence Appraisal

Primary studies were reviewed by two researchers (CE and EVB). All studies involving treatment of hazardous or other non-municipal solid waste were excluded. Each study was assessed for methodological rigor, including exposure assessment, outcome ascertainment, and statistical methods. Where positive associations were found, findings were compared with those of other studies to determine an overall assessment of the likelihood of causation.

Contextual Factors

Key characteristics of the facilities were tabulated, including the dates of facilities operations and emissions levels. Emissions levels of dioxins/furans were sought for all positive studies. If these were not contained in the published literature, then authors were contacted to obtain results.

Results

Twenty-six primary studies met our initial search criteria (Figure 2). Thirteen of these studies were excluded because the waste stream included mixed hazardous or other non MSW waste. Only 13 primary studies assessed incinerators that exclusively burned MSW.

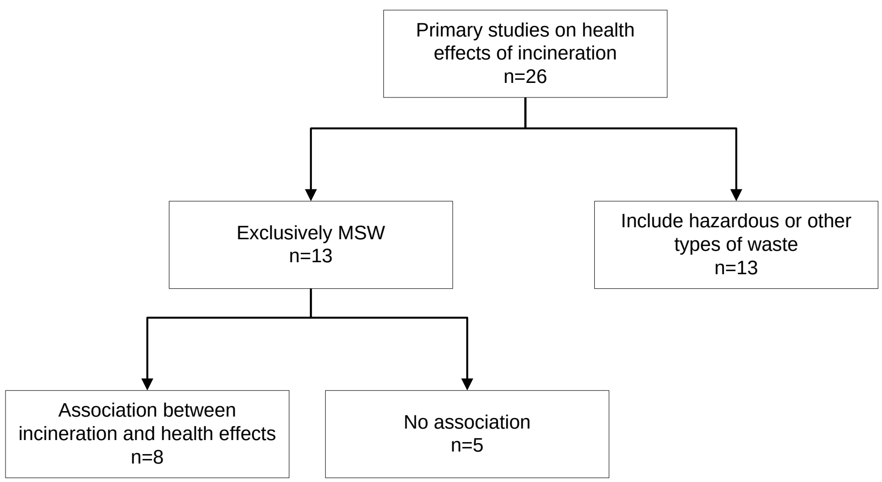

Figure 2.1 *Overview of primary literature on health effects of municipal solid waste (MSW) incineration*

Primary studies of health effects of municipal solid waste incinerators are described in Appendix D. and those of incinerators using multiple waste streams are described in Appendix D.

Thermal Treatment Facility Characteristics

The only residual waste treatment technology assessed in the epidemiologic literature was mass burn incineration. There were no epidemiologic studies of health effects of pyrolysis or gasification.

The dates of incinerator operation were not clearly identified in the studies. Incinerator operation periods were reported as either: (1) the year of outcome ascertainment of health outcome or (2) the years the authors had established as the period during which an incinerator had to be operational in order to be included in the study (Figure 3, Table 3.1). Many of the studies involved incinerators that were operating years to decades prior to the reported study period; although in these cases the periods of operation were not provided. Reported incinerator operation dates ranged from 1971 to 1998.

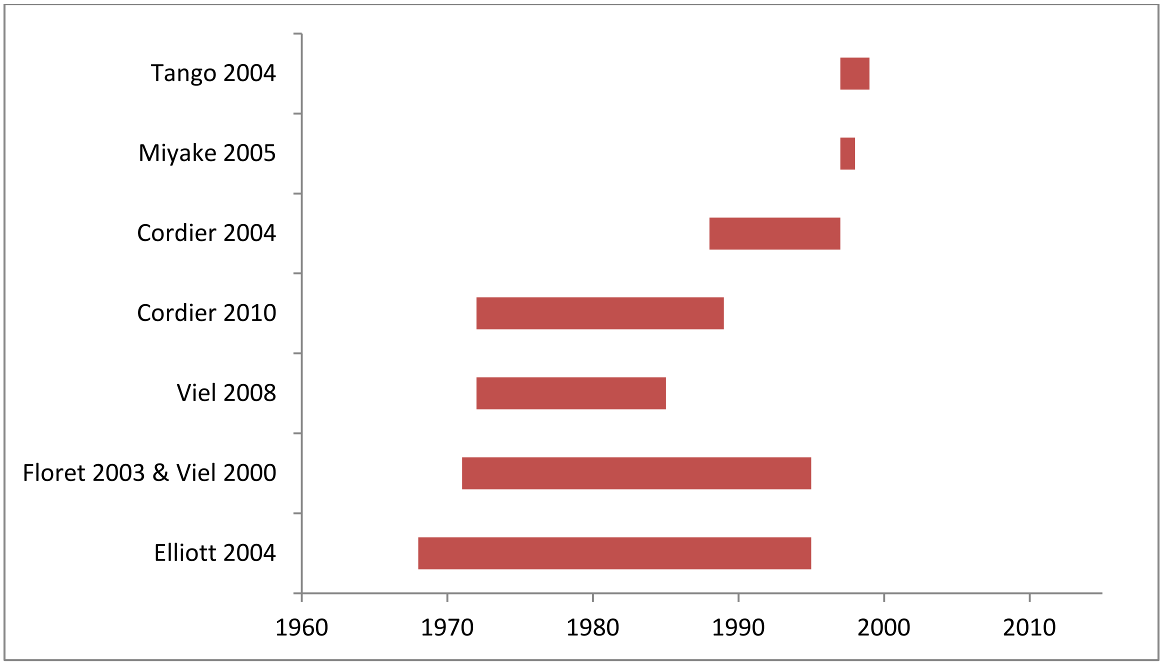

Figure 2.2 *Dates of incinerator operation for primary studies demonstrating health effects*

Exposure Assessment

All seven studies focused their discussions and conclusions on dioxin concentrations, since these were the pollutants of greatest concern around these incinerators. However, exposure assessment methods were generally not specific for dioxins. The Japanese analysis estimated a spatial limit of health effects as the distance from the incinerator.[14,15] The Canadian study[16] set a distance for exposed versus unexposed at 5 kilometres from the facility. The French studies[17-20] calculated emissions of metals and dioxins based on measurement and, when measurements were lacking, expert opinion of emissions concentrations based on incinerator characteristics. Exposure assessment was then based on Gaussian plume models of ground level air concentrations of metals and/or dioxins at receptors. Since dioxin emissions were highly correlated with emissions of metals (Spearmann r = 0.64),[17] dioxin exposures were used to classify levels of exposure. Overall, while dioxins are the basis for discussion and some exposure assessment, metals were emitted from the same facilities and, in France were correlated to dioxin emissions.

Levels of Dioxin Emissions

The dioxin emissions concentrations were reported as peak dioxin emissions, and were estimated differently for those studies with single incinerators versus those with multiple incinerators. When there was a single incinerator, dioxin emissions concentrations were reported as the peak emission concentration from the incinerator. When there were multiple incinerators, dioxins emissions concentrations were reported as the peak emission concentration from the incinerator with the highest peak concentration. Reported dioxin emissions concentrations ranged from 16,000 pg/m^3 TEQ to 80, 000 pg/m^3 TEQ (Table 2).

Table 2.1 *Dioxin emissions in primary epidemiologic studies with findings of association between municipal solid waste incineration and health effects*

Location	Peak dioxin emissions (pg/m^3 TEQ)	Date of incinerator operation reported[d]	Health effects examined (* significant association)	Date of ascertainment of health outcome	Reference
Japan, multiple sites	80,000	1996-1998	Infant deaths*, very low birth weight, infant deaths due to congenital malformations, neonatal deaths, neonatal deaths due to congenital malformations, spontaneous fetal deaths, spontaneous fetal deaths with malformations, female live births, low birth weight, very low birth weight	1997-1998	Tango 2004[14]
Japan, Osaka prefecture	80,000	1997	Wheeze*, headache*, stomach ache*, fatigue*, atopic dermatitis, allergic rhinitis in school children	1997	Miyake 2005[15]
France, Rhone-Alpes Region	16,000	1988-1997	Clefts*, renal dysplasia*, 24 other anomalies (refer to appendix)	1988-1997	Cordier 2004[17]
France, Southeast	16,000	1972-1989	Congenital urinary tract defects*	2001-2003	Cordier 2010[20]
4 regions, France	16,000	1972-1985	Non-Hodgkin's lymphoma*	1990-1999	Viel 2008[18]
Besancon, France#	16,000	1971-1995	Non-Hodgkin's lymphoma*	1980-1995	Floret 2003[19]
Besancon, France#	16,000	1971-1995	Non-Hodgkin's lymphoma* and soft tissue sarcoma*	1980-1995	Viel 2000[21]
Ontario and British Columbia, Canada	N/A	1990-1995	Higher self-report of awareness*, concerns* or actions* among residents living near landfills than residents living near incinerators	1990-1995	Elliott 2004[16]

Both Viel 2000 and Floret 2003 studied the population around the same incinerator in Besancon, France

Distance from Facility

The distance of exposed populations from the facility was not consistently ascertained in all studies. The Japanese studies used spatial analysis that provided a 'limit of health effects' at 2[14] and 4[15] kilometres. The Canadian study[16] set a distance threshold at 5 kilometres for exposed populations. Most French studies[17-19] did not use distance as a measure of exposure, but instead modeled ground level pollutant levels. A single French study used a spatial scan statistic to vary distances from a single facility in order to identify clusters.

[d] Incinerator operation reported was either (1) the year of outcome ascertainment for symptoms or congenital defects or (2) the years in which the authors had set as the period during which an incinerator had to be operational to be included in the study.

Table 2.2 *Distance of affected populations from municipal solid waste incinerators in primary epidemiologic studies*

Location	Type of Study	Distance of affected population from facility (km)	Health effects examined (* significant association)	Reference
Japan, multiple sites	Spatial comparison of observed/ expected ratios	<2	Infant deaths*, very low birth weight, infant deaths due to congenital malformations, neonatal deaths, neonatal deaths due to congenital malformations, spontaneous fetal deaths, spontaneous fetal deaths with malformations, female live births, low birth weight, very low birth weight	Tango 2004[14]
Japan, Osaka prefecture	Ecological	<4	Wheeze*, headache*, stomach ache*, fatigue*, atopic dermatitis, allergic rhinitis in school children	Miyake 2005[15]
France, Rhone-Alps Region	Ecological	Exposed and unexposed communities – no distance provided	Clefts*, renal dysplasia*, 24 other anomalies (refer to appendix)	Cordier 2004[17]
France, Southeast	Case-control	Threshold set at 10km	Congenital urinary tract defects*	Cordier 2010[20]
4 regions, France	Ecological	No distance provided. [Comparison of 90th percentile of exposure to 2.5th percentile]	Non-Hodgkin's lymphoma*	Viel 2008[18]
Besancon, France#	Case-control	No distance provided. [Comparison of very high and very low exposed populations]	Non-Hodgkin's lymphoma*	Floret 2003[19]
Besancon, France#	Ecological	Distance varied using spatial scan statistic	Soft tissue sarcoma* and non-Hodgkins lymphoma*	Viel 2000[21]
Ontario and British Columbia, Canada	Ecological	<5 km	Higher self-report of awareness*, concerns* or actions* among residents living near landfills than residents living near incinerators	Elliott 2004[16]

Both Viel 2000 and Floret 2003 studied the population around the same incinerator in Besancon, France

Discussion

We conducted a systematic review of the epidemiologic literature on health effects associated with thermal treatment of municipal solid waste. We found 13 primary studies on associations between MSW incinerators but no studies on health effects of pyrolysis and gasification.

The majority of primary epidemiologic studies linked health outcomes to dioxins although exposure assessments were not specific to a single pollutant, but either based exposure on: (1) distance from facility or (2) modeling of plumes to estimate ground level of dioxins. In the dioxin models, dioxin concentrations were highly correlated to metals. Therefore while the papers base their conclusions on the health effects of dioxin exposures, individuals were exposed to several pollutants in pollutant mixtures, and the health effects may in fact be associated with exposure to this mixture rather than a single pollutant or group of pollutants. The reported dioxin emissions demonstrate that emissions from the studied facilities were very high, and often exceeded regulatory limits. This is suggestive of high emissions of other pollutants.

Our review of the primary literature suggests that living within close proximity to older MSWI with high dioxin emissions (16,000 to 80,000 pg/m^3 TEQ) were associated with adverse health outcomes: congenital anomalies (clefts, renal dysplasia, urinary tract defects), non-Hodgkin's lymphoma, and self-reported symptoms in schoolchildren.

Permitted dioxin emissions from modern MSWI in Canada, United Kingdom, Austria, Germany, and Sweden are in the range of 50 to 500 pg/m^3 TEQ.[2(p.9-48)] The Canada Wide Standards for Dioxins and Furans Emissions from Waste Incinerators and Coastal Pulp and Paper Boilers sets a target emissions for new and expanding MSWI at 80 pg/m^3 TEQ,[22] and the BC guideline for facilities combusting municipal solid waste is also 80 pg/m^3 TEQ.[23] Emissions permitting for US facilities are based on a different measure of dioxins that is not comparable to Canadian and European measures.

In 2012, the range of permitted dioxin emissions in Canada and Europe (50 – 500 pg/m^3 TEQ) was 32 to 1600 times lower than those associated with adverse health outcomes reported in the primary literature (16,000 to 80,000 pg/m^3 TEQ).

Gaps/Limitations

Three major knowledge gaps were identified: (1) absence of epidemiologic studies on the health effects of modern MSWI, (2) absence of epidemiologic studies of health effects associated with pyrolysis and gasification facilities, and (3) absence of emissions inventories for pollutants other than heavy metals and dioxins (e.g., ultrafines, nanoparticles).

Lessons for Human Health Risk Assessment

Human health risk assessment (HHRA) should be conducted for specific thermal treatment plants because there are knowledge gaps in the epidemiologic literature. HHRA risk estimates should be based on known toxicologic hazards of emitted pollutants rather than published risk estimates from the epidemiologic literature because the emissions from thermal treatment facilities in 2012 are well below those reported in epidemiologic literature and published risk estimates are not relevant to modern incinerators. If new studies are published that provide relevant risk estimates, then this will need to be re-examined.

Generalizability to BC Context

The only operating municipal solid waste incinerator in BC is the Metro Vancouver Waste-to-Energy Facility in Burnaby, BC. This facility is described in Case Study 1 in the appendices to this report. Dioxin/furan emissions measured in routine testing have been below the level of detection (5.1 pg/m^3 TEQ) since the facility was opened in 1988.[24] Dioxin emissions measured in 2007 using more sensitive equipment were 2 pg/m^3.[25(p.44)] Published epidemiologic studies of health effects near incinerators involved incinerators with dioxin emissions that were 32 to 1600 times greater than current regulatory standards, and 8000 to 40,000 times greater than emissions measured at the Burnaby MSWI.

Burnaby incinerator operates to a standard that is better than the regulatory standard for all measured emissions, including: dioxin/furans, particulate matter, nitrogen oxides, carbon monoxide, sulphur dioxide, and metals (cadmium, lead, mercury, and Classes, 1, 2 and 3 metals). Future thermal treatment facilities will be required to operate to the regulatory standard.

Section 3: Health Assessment for Municipal Solid Waste Management

In the previous section of this report we reviewed how thermal treatment of municipal solid waste affects health, and concluded that emissions from well-sited waste management facilities following current regulations[e] are unlikely to adversely impact health. Nonetheless some uncertainties remain, and we recommend that human health risk assessment be conducted. It is now recognised that the point source, the treatment facility emissions, are not the sole health concern, but instead it is a suite of activities along the entire system from waste production to disposal that influence health. The key factors are how much waste is produced, which substances are separated out, how waste is transported and the distribution of risks and benefits among population subgroups. Structural and socio-economic factors are at play, and regulatory and policy solutions, such as limiting waste production, reducing inequitable distribution of effects, and designing transport routes to avoid populations, will be most effective.

In this section of the report we illustrate what public health professionals can do, and have done, to ensure that the health impacts of waste management decisions are considered when they matter. We also examine existing policies and regulations that govern waste management in BC and identify when health effects are currently considered within decision-making processes. We define the common methods of health assessment, and identify health impact assessment (HIA) as a promising tool. We describe eight case-studies from within BC and internationally, which illustrate how health assessments have been conducted for waste management policies, options and facility plans, and which comprise a wide range of health assessment methods, and contributions to decision-making processes. These examples provide models of public health professions working across disciplines to provide health input to decision-making processes. We also describe how stakeholders have responded to situations where the health effects of waste management proposals were not assessed. These inform our assessment of when HIA is a useful tool and when it may be unnecessary. We then focus on the organizational structures that supported HIAs in the case studies, in order to better understand what expertise and resources are necessary to conduct HIA. Finally we propose a comprehensive approach to health assessment for waste management in BC. This approach incorporates lessons learned in the evidence review and case studies. It builds upon current health assessment processes in BC by addressing current gaps in health assessment. The process is flexible, and can be simple or complex depending on the specific information required for each waste management decision. The general process could be adapted for other health issues that involve complex technologies, potential health impacts and public concern.

Which waste management decisions have potential to affect health?

A few key factors largely determine the nature and distribution of health outcomes arising from waste management policy and practice: the characteristics of the waste; the scale of thermal treatment facilities; the technologies used for thermal treatment; and emissions control and the location of the facility. Waste reduction, sorting and diversion[f] policies determine waste characteristics. Waste

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[e] Current regulations are those at the time of writing (Fall 2012).

[f] Waste diversion is the removal of waste from the waste stream for recycling, composting or other purposes prior to final disposal.

characteristics, in turn, influence the waste transport volume, feasibility of treatment technologies[g] and contaminants in emissions. MSW may be treated in a number of smaller neighbourhood scale facilities, a single large facility or a combination of these (Table 1).

The type of technology used for thermal treatment and emissions control will influence the composition of air emissions, water effluent, and solid wastes produced, as well as the energy offsets. The choice of facility site will influence the selection of transportation routes and therefore the populations that would be potentially exposed to traffic related impacts along those routes (i.e. effects of emissions, motor vehicle crashes). A combination of these factors will influence the nature and number of jobs created.

These key factors influence health through multiple pathways and mechanisms which may be grouped into those related to the changes in the physical environment and those related to changes in social determinants of health. Health effects related to the physical environment may be further divided into those attributable to emissions to environmental media, and those related to other changes in the physical environment such as traffic, noise et cetera. This distinction is important, because emissions are regulated under WDA, whereas other changes to the physical environment are not and because different methods are used to assess health outcomes potentially arising from each type of change.

Consider the volume of waste, for example. As the volume of waste is increased, there will be greater transportation requirements and associated fuel consumption and emissions. The waste transfer stations and disposal facilities must be either more numerous or larger, and ultimately have greater emissions to the environment with greater potential for health impacts. Emissions from transportation and treatment facilities will be greater, and the potential for direct health effects also greater. Of course, these factors may be mitigated by factors that reduce individual exposure (e.g., choosing transportation routes and facilities' sites distant from populations), appropriate air pollution controls and other factors. The increase in transportation will also lead to an increase in changes in the physical environment that are not related to emissions such as noise and traffic volumes, each with their own health impacts. Social and economic factors are also influenced through the volume of waste. A waste management system with greater capacity will employ more workers. Employment and relative economic status, in general, contribute to good health. Each waste disposal scenario is unique and will require individual assessment in order to determine potential hazards, population exposures and associated risks to health as well as potential health gains. Health effects of different waste management scenarios may have subtle difference that can be detected by modeling using local information. By teasing apart the myriad ways in which waste management affects health, it becomes clear that the residual treatment facility is not the only, nor the most important, influence on health outcomes. Rather, decisions made throughout the process from waste management planning to facility implementation can have important health impacts. In order for decisions about these key factors to be optimized for health, health must be considered alongside economic, technical and other factors in these decisions.

[g] Thermal treatment technologies have various requirements for volume and calorific value of the waste stream in order to be feasible.

Table 3.1 *How municipal solid waste management decisions may affect health*

<table>
<tr><th>Waste management decision</th><th>Intermediate factors</th><th>Potential health impacts that should be considered in decision-making.</th></tr>
<tr><td>Waste reduction and diversion targets</td><td>Volume of materials consumed
Volume of transportation of raw waste from curb side to facility and of residuals from facility to final disposal site,
Volume of air and water emissions from facility,
Volume of residuals and waste from pollution control,
Waste composition</td><td rowspan="4">Materials extraction and goods consumption: health impacts related to natural resources extraction, goods manufacture and transport of goods (generally beyond the scope of waste management policy and plans).
Facility related emissions, air pollution control devices and waste residuals: estimate attributable burden of disease from emissions to air, water and other environmental media from facility and waste disposal (residuals, air pollution control waste)[h] for receptors representing a range of exposure scenarios and vulnerable populations.
Transportation emissions: estimate attributable disease burden (e.g., respiratory events, cardiovascular events, incident asthma, injury) and distribution of transportation effects based on transportation routes.
Energy offsets: estimate health impacts based on amount of energy produced, type of energy production that is offset (emissions reductions) and changes in distribution of effects.
Scale and location of facilities: estimate distribution of health effects among population subgroups related to location of the site. Options for scale and location should be compared with regard to local effects, transportation routes, employment and economic impacts on the local economy, and health-related effects of land use trade-offs.
Construction-related worker influx: estimate health effects of worker influx on communicable diseases, social capital and cohesion, employment and economic impacts, access to health services.
Facility operations: estimate health effects of dust, noise and light related to construction and operations of facility.
Employment and economic considerations of above.</td></tr>
<tr><td>Composition of waste treated</td><td>Composition of facility emissions, waste residuals and pollution control waste</td></tr>
<tr><td>Location(s) and scale(s) of facilities</td><td>Transport routes, Distribution of populations affected
Construction-related influx of workers, noise and air emissions
Facility related odour, noise, and light.</td></tr>
<tr><td>Technology for waste treatment and air and water pollution control</td><td>Energy offsets
Emissions to air, water, land and deposition on land
Pollution control waste</td></tr>
</table>

[h] In general, the existing regulatory guidelines for air pollution control are protective of health. However, there may be certain exposure scenarios for vulnerable populations that are not anticipated in the regulations. Therefore modeling these risks is recommended for each proposed facility.

Health assessment in the municipal solid waste treatment decision-making process in BC

The decision-making process that leads to the operation of a MSW treatment facility[i] begins with MSW policy and is completed when the facility becomes operational. This process occurs in four stages (Figure 1):

(1) Policy: regional waste management policy is set,

(2) Facility Options: the waste management facility[j] is chosen from submitted proposals,

(3) Facility Plan: the waste management facility plan is approved, and

(4) Facility Operations: the facility is authorized to operate under permits from Ministry of Environment.

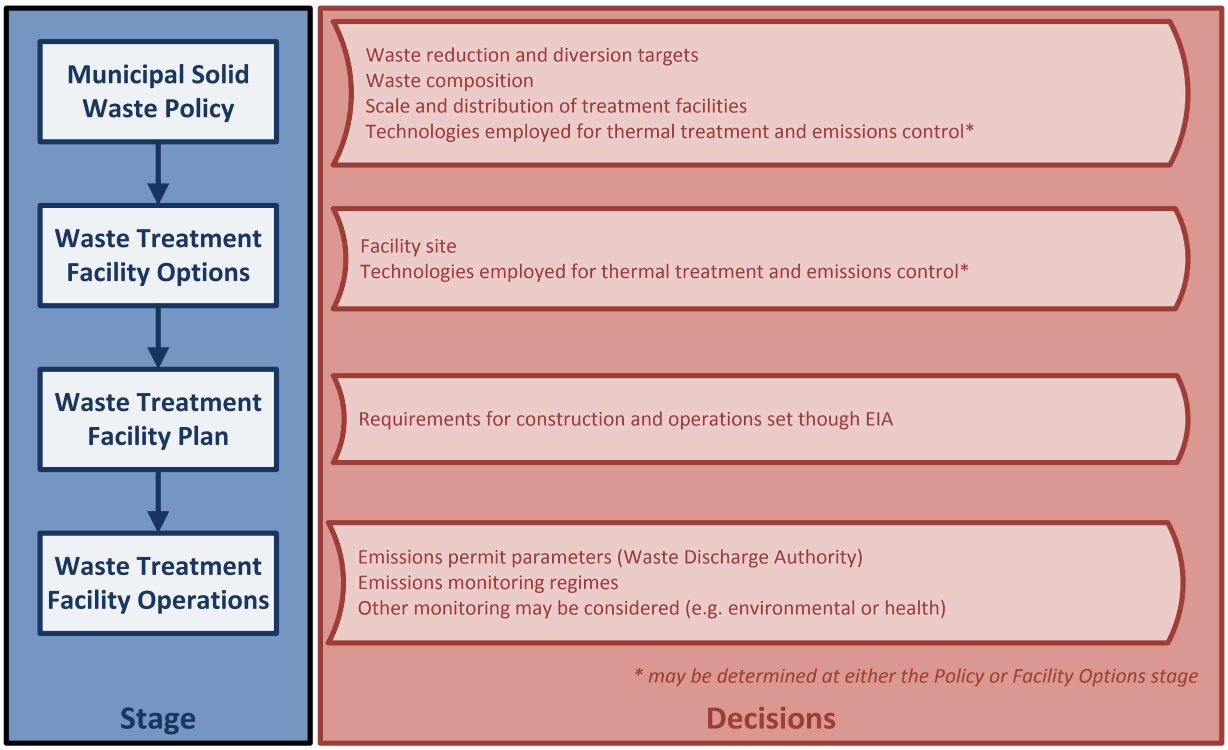

Figure 3.1 *Decision points for consideration of health effects of municipal solid waste management policy and processes*

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[i] This discussion focuses on the steps from policy to the operations of a thermal treatment facility and does not include other aspects of waste management that have potential health impacts such as the methods of recycling or composting. This limitation is based on the scope of the project as outlined by the Environmental Health Policy Advisory Committee. However, many of the general principles of health assessment presented here do apply to these other aspects of waste management.

[j] The term 'facility' is used for clarity of writing, however it is recognised that a MSW treatment plan may include one or several facilities.

Key decisions are made at each stage. During the policy stage the regional district determines the type of disposal method (e.g., landfill or thermal treatment), and waste diversion and reduction targets. This forms the basis of the request for proposals. During the options stage the regional district puts out an expression of interest followed by a request for proposals and selects the waste management facility. This decision determines the proponent, technologies for thermal treatment and emissions control, and the facility/facilities site(s). The number and scale of facilities may be set during the policy stage or the options stage. The planning stage is when the details of construction and operations of the facility/facilities are laid out. Projects that meet certain criteria for the amount of waste handled or amount of energy produced will trigger the BC environmental impact assessment process (EIA).[k] EIA is a process that requires a detailed assessment of the environmental impacts of facility construction and operations. Under the Environmental Assessment Act, the scope of the EIA is determined by the Executive Director of the Environmental Assessment Office (EAO), and historically has included an assessment of environmental effects and recommendations for permitting and monitoring criteria. Assessment of health impacts of a project may be conducted at the discretion of the Executive Director of the EAO. Upon review of the EIA the Minister of the Environment determines whether a project will: (1) receive an environmental assessment certificate allowing it to proceed with any conditions they consider necessary, (2) require further study or assessment or (3) be refused an environmental assessment certificate and thereby be halted. During the operations stage a facility is required to meet certain emissions standards as outlined in the waste discharge authorizations (WDAs) issued by the BC Ministry of Environment (MOE). MOE specifies emissions monitoring requirements and these are often based on recommendations in the EIA. Different MOE regulations and guidelines are applied to the construction phase versus the operations phase. Any upgrades to the facility may also need to be permitted by the Ministry of the Environment depending on the nature and scale of the modifications.

The current practice of health assessment for waste management in BC is summarised in Table 2. In summary, health is usually, but not consistently, considered in the facility plan and operations stages only during EIA and WDA. Current practice has three major shortfalls. First, decisions made during policy and options stages have important implications for health, but impacts on health are not routinely considered during these earlier stages of the decision-making process. For example, decisions made at the policy and options stages determine allowable waste volumes and constituents, waste reduction and diversion targets, energy offsets, technologies, scale and location, and costs (Table 2). Therefore the health impacts of options considered at these earlier stages should be characterised and form part of the criteria to make those decisions alongside economic, political and other factors. Second, health assessment is not legally mandated within the EIA process, but rather is at the discretion of the Executive Director of the EAO. The current practice is to conduct a health assessment when there are health concerns; however, with no legislated requirement, this could change at the Executive Director's discretion. Third, when health assessments are conducted during EIA and WDA processes, they are generally limited to the health effects associated with facility emissions to environmental media (i.e. soil, water, air) and do not consider effects mediated through other physical (e.g., traffic injury), social (e.g., employment) or other processes. If the full scope of health effects of these decisions is to be examined then health assessment during EIA should be broadened to consider the range of factors widely accepted to affect health (i.e. take a determinants of health approach).

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[k] Environmental impact assessments are triggered when energy production threshold is ≥ 50 MW or mass of municipal solid waste incinerated ≥ 225 tonnes/day. The executive director of the Environmental Assessment Office may waive the project requirement if it is considered that the project will not have adverse environmental, economic, social, heritage or health effects and the Minister of Environment may designate a project reviewable if the project has significant adverse effect or if it is considered in the public interest.

Table 3.2 *Characteristics of waste management with potential health impacts, and whether health impacts are assessed to inform these decisions in BC*

Characteristic	Health Impacts Assessed
Policy/Options	
Energy offsets – risks and benefits related to energy generation and decreased use of other energy sources	Health impacts are not routinely assessed.
Options for technologies, scale and location of facilities – relative health impacts on population subgroups	Health impacts are not routinely assessed.
Waste reduction and diversion targets	Health impacts are not routinely assessed.
Costs of waste management options	Health impacts are not routinely assessed.
Project	
Physical environment	
Facility emissions	Health impacts are routinely assessed during the environmental impact assessment and waste discharge authorization processes.
Transportation emissions	Health impacts are not routinely assessed.
Non-emissions related changes to the physical environment (transport-related injury, noise, dust, et cetera)	Health impacts are not routinely assessed.
Socio-economic environment	
Construction-related worker influx	Health impacts are not routinely assessed.
Employment	Health impacts are not routinely assessed.
Other (e.g. real estate prices, displacement of populations)	Health impacts are not routinely assessed.

Health impact assessment: a tool for considering health in decision-making

If health is to be considered at each stage of decision-making, then the health impacts must be characterized for these stages. Health impact assessment (HIA) is a process that can be used to identify and predict health impacts of policies and programs using quantitative and/or qualitative methods. A widely accepted definition of HIA is: "a combination of procedures, methods and tools by which a policy, program or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population".[55]

HIA is designed to support decision-making by characterising and highlighting differences between the health effects of the different options that are under consideration. Both positive and negative health impacts are considered. Evidence for the appraisal of health effects come from public health, epidemiology, toxicology, and perceptions of communities and other stakeholders and the methods for a particular HIA are chosen to elicit the information required to inform a specific decision. The guiding principles of HIA are democracy, equity, sustainable development, ethical use of evidence and comprehensive approach to health.[56]

Tools and approaches to HIA abound and can be found in the published literature and on the internet from government and organizations.[56-59] The specific steps vary, but generally include (1) Screening, (2) Scoping, (3) Appraisal, (4) Reporting and (5) Monitoring and evaluation (Figure 2). Each step will not be described here, but readers are directed to the guides cited above for further detail.

One of the key principles of HIA is a broad definition of heath. HIA is based on the widely accepted tenet that factors beyond the simple absence or presence of disease affect people's health. These factors include biological, physical, community, social, economic and other determinants of health.[54,l] Those determinants that are potentially modified by waste management include those relating to the physical environment, as well as those related to the social factors. These are collectively referred to as the "social determinants of health" and include such factors as employment and working conditions, housing, and social exclusion.[m] An early step in the HIA is to identify those determinants of health that are most affected by the decision. Then the evaluation is focused on comparing how each option affects these determinants.

HIAs range in their comprehensiveness. Rapid HIA is completed in a matter of weeks using existing knowledge and information and no stakeholder involvement. Intermediate HIA is completed within several months using analysis of previously collected data (often administrative data) and some stakeholder involvement. Comprehensive HIA takes months to years and involves collection of new data and significant stakeholder involvement. HIA may be independent or may be conducted within existing processes such as EIA or WDAs.

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[l] The Public Health Agency of Canada recognises 12 determinants of health: Income and social status; Social support networks; Education and literacy; Employment/Working conditions; Social environments; Physical environments; Personal health practices and coping skills; Healthy child development; Biology and genetic endowment; Health services; Gender; and, Culture.[60]

[m] The social determinants of health are a series of economic and social factors that influence people's health. They are variously defined and the conditions of living[61] or using a list of specific determinants, for example the 14 social determinants of health framework: income and income distribution, education, unemployment and job security, employment and working conditions, early childhood development, food insecurity, housing, social exclusion, social safety network, health services, aboriginal status, gender, race, disability.[62]

Health Assessment Methods

HIA, EIA and WDA are all *processes* used to assess health impacts. A variety of *methods* are used to characterise health impacts, and these are not limited to a specific process. Instead, some methods are better suited to address certain types of health impacts. The most common methods are described briefly here and in greater detail in Appendix E.

Human health risk assessment (HHRA) is quantitative approach that uses associations between specific environmental parameters and health outcomes that have been established through epidemiologic and/or toxicologic research. HHRA uses these associations to predict health outcomes caused by projected environmental emissions. These predictions inform a risk management strategy that outlines project/policy options and associated health risks. HHRA is limited to substances/emissions that are measured and for which toxicity and dose-response relationships are known. Health outcomes arising from changes in the physical environment other than emissions (e.g., noise) and those arising from changes in social determinants of health are not amenable to HHRA methods.

Quantitative methods are also used to assess health impacts related to other non-emissions changes to the physical environment (e.g. noise, traffic). These include GIS mapping and statistical techniques to demonstrate patterns in exposures through space and time.

Semi-quantitative techniques such as ranking the likelihood and/or severity of effects on a Likert scale can be used across all potential health effects. This method is used to provide a comparative analysis of options based on certain criteria. They are also effective at engaging a broad group of stakeholders in assessment, since they can be designed to be used by those without technical expertise. When stakeholders are included, the objectives of the assessment can be two-fold: (1) the prediction of potential health impacts and their direction (negative/positive) and (2) community involvement in decision-making.

Qualitative techniques include narrative reports, case studies and scenarios. These are often employed to assess social determinants of health. The strength of qualitative techniques lies in their ability to bring together evidence from a broad range of sources and to provide an interpretation of potential outcomes based on analogy and scenario.

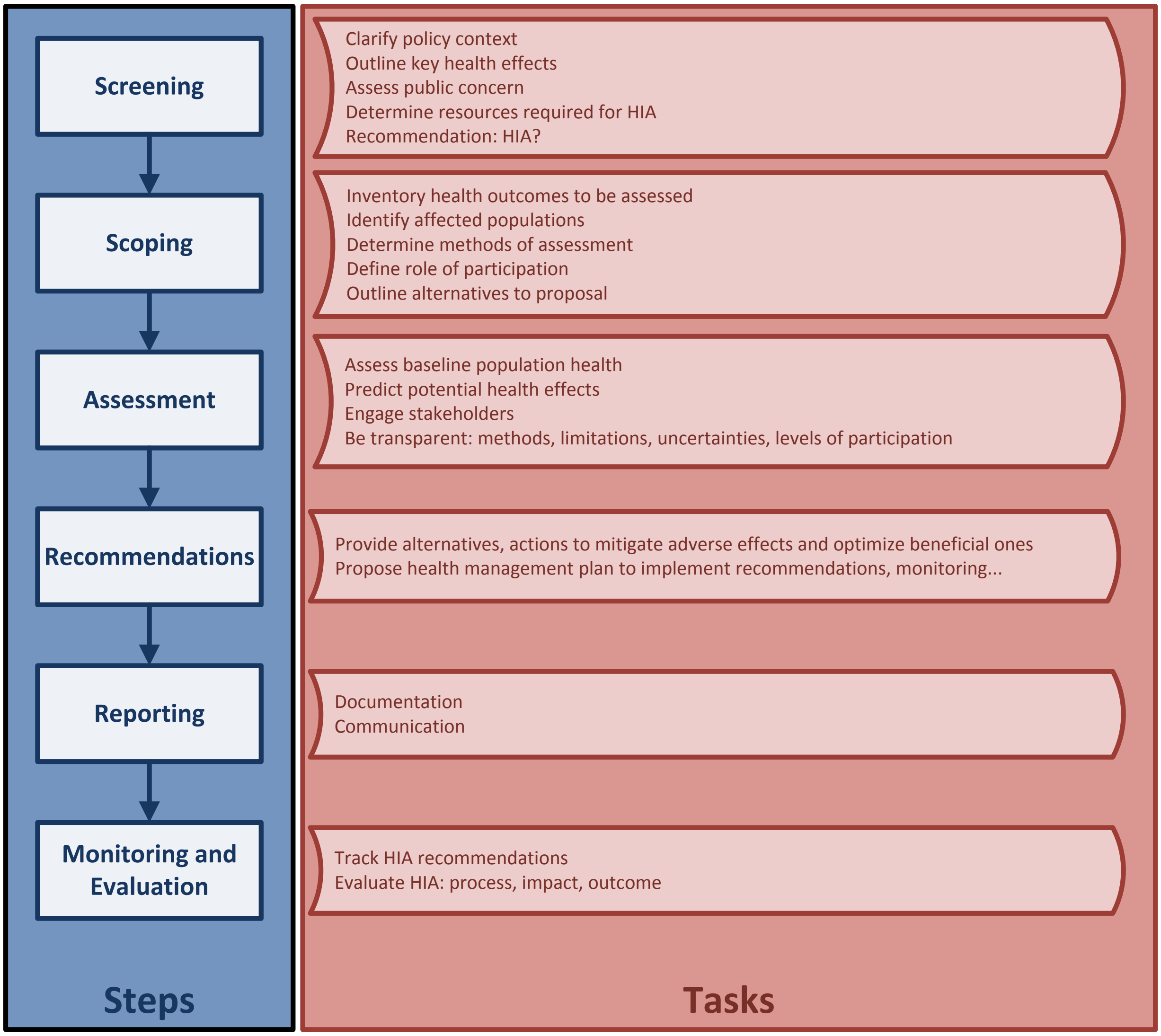

Figure 3.2 *Health impact assessment process*

Case Studies: How have health effects of municipal solid waste policy and projects been assessed?

Given HIA's broad definition and the range of methods employed, it may be difficult to envision how HIA could be practically applied to municipal solid waste policies and projects. We conducted an environmental scan of health assessment (HA)[n] for solid waste management. We sought case studies for each of the four stages, but only found them for the plan, options and policy stages. This section provides critical analyses of eight of these case studies. Specifically we address the questions:

(1) What were the objectives and methods of the HA?

(2) What were the roles of health assessment experts and those of stakeholders in leading and/or conducting the health assessment?

These are compared with case studies in BC where health assessment was not conducted. Detailed descriptions of the Kamloops and Toronto case studies are provided in Appendix E and F respectively.

Health assessment in the Policy Stage: informing waste management policy

Wales

The country of Wales integrated health impact assessment into their development of a Draft Wales Waste Strategy.[65,66,o] The objectives of this policy level HIA were to evaluate the potential environmental impacts and socio-economic impacts of national, regional and local waste management policies and to develop a health management plan with recommendations for national, regional and local levels. The HIA was conducted by a consultant group. A steering group comprised of government bodies and academics[p] commented on the initial scoping and the final assessment. The health management plan provided a comprehensive assessment of the health implications of the policy for national, regional and local governments.

The HIA was comprehensive in its description of how HIA could be applied throughout waste management decision-making from policy to operations. It made specific recommendations for: (1) HIA at the regional level "to support site and technology selection and inform decision making during specific applications and environmental permitting" (p.46), and (2) HIA at the facility plan stage be coordinated with EIA. At the Plan Stage HIA was put forward not only as a method to characterise potential risks to public health but also as a tool to facilitate community understanding of the difference between actual and perceived risk.

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[n] Health assessment refers to any process whereby the potential health effects of a policy, plan or project are predicted or described. It is a general term which encompasses human health risk assessment, health impact assessment and other processes with the objective of assessing health effects.

[o] Two HIAs were performed in series: (1) an HIA of the three regional waste plans[11] and (2) an HIA of the national Wales Waste Strategy.[10] HIA at the regional level was used to compare scale, likelihood and distribution of health impacts of various waste management options, and is not discussed here.

[p] The steering group was comprised of members of the Sustainable Development Commission, the Welsh Health Impact Assessment Support Unit, the Environment Agency, the Welsh Assembly Government and the University of Wales.

Cardiff

Two years after the Wales policy level HIA was completed, the City of Cardiff (Wales) considered building a waste to energy facility to treat its MSW. An HIA for the proposed facility was completed by the Wales Health Impact Assessment Support Unit (WHIASU) in consultation with community stakeholders. However this HIA was excluded from local government processes, and community concerns were not heeded when the facility was approved.[53] WHIASU experts suggested that the acceptance of the HIA at the local level was limited since HIA was not a statutory requirement, local planners did not understand the benefits of HIA, and they may have even perceived HIA as a protest tool.[67] In contrast, the strong support for HIA in the Wales Waste Strategy came after working closely with WHIASU over a number of years. Furthermore, HIA is a compulsory requirement for national and regional waste strategies in Wales.

Vancouver

Metro Vancouver developed a Solid Waste and Resource Management Plan in July 2010 which proposed waste management practices to 2020 including waste reduction and diversion targets, treatment methods, energy recovery and final disposal.[68] The plan included economic and environmental assessments but not a health assessment. The completed plan was presented to public health officials, municipal representatives, the public, and other stakeholders in a number of community consultations. The public health practitioners in the two affected regional health authorities were concerned with the absence of analysis of the public health impacts. There was also a high degree of community concern regarding the potential adverse environmental and health effects of a proposed waste-to-energy facility. The outcome remains uncertain since this process was still underway at the time of writing.

Summary: health assessment in the Policy Phase

These examples illustrate the benefits and limitations of HIA at the policy level. The Wales and Cardiff case studies illustrate that while health considerations may be well integrated into policy, politics at the local level may exclude health impacts during the planning and implementation stages. At the same time, the widespread education and capacity building conducted by WHIASU at the national level have led to understanding of and support for HIA principles that should trickle down to the local level with further capacity building. This illustrates the model where HIAs are integrated throughout waste policy, planning and projects. It was achieved through years of partnership between policy makers and planners and experts in HIA (WHIASU), and will require further partnerships with local government planners and decision-makers in order to be fully realised.

In Metro Vancouver the absence of a health impact assessment likely contributed to the degree of public concern about the Solid Waste and Resource Management Plan in general, and specifically to resistance to a proposed waste-to-energy facility by multiple stakeholders. Nonetheless both Metro Vancouver and the public health practitioners have engaged in communication with each other about health assessment for proposed facilities so it still remains to be seen whether a health assessment will be conducted and the nature of such an assessment.

Health assessment in the Options Stage: comparing health effects of proposed facility options

Two case studies demonstrate the use of HA to compare waste treatment facility options. The objectives of the HA in each case led to two very different approaches.

United Kingdom

The UK Department for Environment, Food and Rural Affairs used a standard HHRA methodology to estimate and compare health impacts of emissions from 10 hypothetical waste management treatment facilities representing five treatment technologies.[8] This analysis was restricted to air emissions from waste facilities, which have been identified as one of the key potential sources of health impacts. The authors concluded that all facilities, regardless of treatment technology, had minimal health effects. This assessment provided a comparison among treatment options in a standardised manner, but by design it was limited to a specific exposure-outcome pathway: exposures to air emissions and attributable respiratory, cardiovascular and cancer endpoints. It did not assess other emissions/exposure pathways, did not consider non-disease endpoints, and it did not model the distribution of health effects among population subgroups.

Toronto

City of Toronto Public Health oversaw an HIA to compare differential health effects of three waste treatment options under consideration in the 2010-2021 waste management plan. The assessment was conducted by a consultant. Waste treatment options were evaluated across a broad range of health determinants based on 'level of concern' for health. The evaluation was conducted by a working group including City of Toronto public health and waste management staff members and the consultant. In the final analysis the environmental determinants (emissions to the environment, noise, et cetera) were found to best discriminate between the options, and formed the basis of the final ranking. The option that was favoured by the HIA was also the option subsequently selected by the waste management department using their own operational criteria. The report to the board of health suggests that this HIA influenced the waste management department's decision on a mixed waste treatment option.[24] However, the waste management department's decision was also influenced by their own internal process that favoured this option based on operational criteria. This HIA allowed a rapid evaluation of options across a range of determinants of health and brought together a working group from public health and waste management within the City of Toronto. Community stakeholders were not engaged in this HIA, but were engaged in a subsequent HIA at the Plan stage.[q] However, it is difficult to assess the methodology used in this HIA since criteria for assessing 'level of concern' were not described.

Summary: health assessment in the Options Phase

Both of these examples demonstrate how HIA has been used to discriminate between options for treatment of residual waste in the project planning stage for either hypothetical (UK) or proposed (Toronto) waste management facilities. At this stage the HIA has potential to influence the type of technologies and facility site; however in these examples HIA was restricted to comparing technology options. It is not clear whether these HIAs were used to inform decision-making because in the UK case the analysis was removed from a specific proposal, and in the Toronto case public health and solid waste management both favoured the same option, albeit using different criteria. In both cases the assessment focused on health outcomes mediated through environmental emissions. Although the Toronto case considered other social determinants of health in its initial analysis, these were felt to be less valuable in discriminating among options than environmentally mediated effects. In both cases the HIA was led by groups with expertise in health assessment, and other community stakeholders were not involved.

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[q] Toronto Public Health conducted a second HIA once the site and facility for residual treatment were determined which is described in Appendix 3.

Health assessment in the Plan Stage: evaluating health effects of a proposed facility

Durham

In Canada the usual practice is to conduct health assessment solely within the environmental impact assessment process. This is exemplified by the health assessment conducted within the EIA for a waste-to-energy project in Durham, Ontario. The primary objective of this assessment was to quantify health risks of emissions to environmental media (air, water, soil) using human health risk assessment (HHRA) methodology and to compare these to accepted standard risks. As is often the case, this HHRA was limited to effects of environmental emissions on a set of diseases rather than other social determinants of health. However, in addition to the quantitative results from the HHRA, the final report also listed potential effects on social, cultural, and economic environments, and proposed methods to mitigate impacts (for example, a community relations plan to mitigate potential effects on property values). The strengths of this assessment were the methodological rigor of the quantitative assessment and that in contrast to typical HHRA within EIA, this analysis identified some potential effects on social determinants of health. Some weaknesses of this assessment include (1) incomplete assessment of determinants of health, (2) equity, the differential distribution of health effects among population sub-groups, was not formally considered, and, (3) the assessment was designed and conducted by a consultant under the directive of the EA office and did not involve a range of stakeholders in either defining the scope or contextualizing the findings. These issues are common to health assessments conducted for the purpose of EIA, and are not limited to this project.

Jersey

The health assessment for a proposed waste-to-energy facility in Jersey,[r] UK took a completely different approach in both the definition of health and the methodology. This assessment was commissioned by the States of Jersey Department of Health and Social Services and conducted by an international consortium affiliated with the World Health Organization.[s] Oversight was provided by a steering group composed of representatives from a range of stakeholder groups.[t] The objectives were to identify the potential health effects of a proposed waste-to-energy facility and to characterise their distribution. Health was broadly defined using a social determinants of health framework. The methods were highly participatory and focused on building consensus among stakeholders and community members (e.g., community consensus-building meetings, Delphi method). The final analysis listed health impacts and classified them according to their direction (positive/negative), relative likelihood and latency. Recommendations included mitigation measures for these impacts. The strength of this HIA was its participatory approach: it brought stakeholders together and developed a common view of potential health impacts and mitigation measures. The major weakness was a lack of detail in the assessment, which the authors conceded was due to tradeoffs between the decision-making timeline and the comprehensiveness of this study.

[r] Jersey is one of the Channel Islands situated in the English Channel off of the French coast of Normandy.

[s] International Health Impact Assessment Consortium at University of Liverpool.[63]

[t] The HIA steering group was comprised of representatives from the Departments of Health and Social Services (Public Health), Transport and Technical Services, Planning, HIA and EIA consultants and the community.

Kamloops

The case study of a proposed microgasification plant in Kamloops demonstrates the possible pitfalls of not consulting communities early in the planning phase of a project. A private corporation was proposing to build a plant to thermally treat logs impregnated with creosote using microgasification technology within the City of Kamloops, BC. The proponent did not consult either public health officials or the public until the project was well developed. In their assessment of permitting requests, public health officials assessed the health risks to be minimal but did not address some key concerns of the public. The public brought in an expert from the United States who presented on potential adverse health effects at a community meeting. By the time that a public consultation process had begun, many members of the public were highly concerned about health risks and they had a high degree of mistrust of both the proponent and public health officials. The public had high degree of outrage[u] and the proponent withdrew the project.

Summary: health assessment in the Plan Phase

These examples of health assessment (HA) during the planning of individual waste management facilities illustrate the potential roles of HA at the Plan Stage. HA can be used to identify and characterise potential health effects and their distribution in the population. The methods of assessment may be quantitative or qualitative and suited to the objectives of the HIA. It is not possible at this stage to use HA to inform either the choice of treatment technology or the site, since these were determined in prior stages. However, HA can be used to inform a health management plan that recommends measures to mitigate adverse health effects and enhance health benefits. These HAs had different governance structures. In Durham consultants conducted the health assessment as part of an EIA process. In Jersey the department of health commissioned a consortium with expertise in HIA, and a multi-stakeholder board oversaw the process. The role of HIA in achieving a shared understanding among stakeholders should not be underestimated, as this was a key role for HIA in the Jersey case study and was identified as a potential contributor to public outrage in the Kamloops case study.

Lessons Learned: health assessments for municipal solid waste policies and projects

The case studies were examined to determine:

(1) What were the objectives and methods of the HA?

(2) What were the roles of health assessment experts and those of stakeholders in the assessment?

Objectives and methods of the health assessment

This series of case studies illustrates health assessments at the policy, facility options and facility plan stages. They encompass health assessments that that were limited to health impacts of changes to the physical environment and those that assessed health impacts of changes to the physical environment and the social determinants of health.

Health assessments limited to assessment of health impacts related to changes in the physical environment did not go through the typical HIA process as outlined in Figure 2. Rather, they either used the EIA process (Durham) or conducted HHRA without record of screening or scoping (DEFRA). The method of assessment was an HHRA approach based on HHRA where quantitative methods were used

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[u] Outrage is defined as excessive fear or anger about a small hazard and is related to factors such as trust, control, voluntariness, dread and familiarity.[64]

to assess health impacts. In order to use this approach, specific information about the facilities (e.g. scale, number, technologies, and adjacent populations) must be known and therefore they are suitable for estimating potential health impacts of proposed facilities, either for comparing proposals or informing approval of a single facility. This method is also applied at the operations stage, to model health impacts of emissions. We did not find an example of HHRA at the policy stage; however, it could be applied, for example to calculating potential health impacts of proposed waste reduction and diversion targets.

Those assessments that did use the HIA process, whether at the plan, options or policy stage, generally shared a broader set of objectives: (1) to identify health impacts, (2) to characterise health impacts and their distribution, (3) to inform decisions, (4) to recommend ways to mitigate health impacts and measures to enhance health, (5) to identify stakeholder concerns and address them in the health assessment thereby facilitating a common understanding of health risks and benefits among multiple stakeholders. HIAs at each of the decision-making stages targeted their assessments to provide information for a specific decision. At the policy stage, arguably the decisions that will most affect health outcomes were made: how much waste will be allowed, how it will be segregated and in broad brush strokes where and how it will be treated. HIA was designed to evaluate social and economic implications of the decision and to develop a health management plan. At the options stage, HIA provided estimates of the different potential health impacts of various proposed facilities so that health benefits and risks of each scenario can be compared. At the facility plan stage, the inputs to a health assessment are more specific: the details of physical changes to the environment (e.g. emissions and traffic) and social determinants of health, population characteristics and vulnerabilities. At this stage the predictions of health impacts, regulatory and monitoring regimes and management plans are more specific. However, only minor changes to the waste management facility and operations can be made and therefore there is limited potential to influence health outcomes.

The Kamloops, Vancouver and Cardiff case studies all illustrated that the concerns of the public and the public health communities can be heightened if health effects are not explicitly considered at the project and policy stages whereas the Jersey case study demonstrated how HIA can be used to identify and address public and public health concerns and reach a common understanding. The Cardiff case study also showed that even when HIA has broad community support it can be ineffective at informing decisions if it is excluded from planning processes.

HIA is not the best tool for all situations. HIA is useful when there is a real or perceived risk to human health. In the former situation it can identify, characterise and propose ways to mitigate the risk, and in the latter it can characterise the risk and bring stakeholders' disparate views to a common understanding. HIA is useful when there are a number of options being considered and there are differences between them in the magnitude or health effects and/or the distribution of those effects among population sub-groups. At both the facility plan and facility operations stages standard planning and regulation for facilities may be sufficiently health protective, in which case HIA should only be considered if there is concern among stakeholders. In addition, HIA should be considered if there is a characteristic of the facility that renders it different from those with known or modelled impacts. For example, facilities using technologies which have not been tested at the scale of the proposed facility, and facilities which are closer to populations and vulnerable population subgroups. These are important considerations because in these cases existing environmental and health protection regulations may not adequately protect health. HIA is generally not useful for projects operating far from populations, using known standard technology when existing regulations are protective of health and there is no stakeholder concern.

Table 3.3 *Roles of HIA in specific situations*

Situation	Role of HIA
There is uncertainty about health impacts of project/policy for example due to new technology, scale, site or populations potentially exposed.	List health impacts and characterise their magnitude and distribution among population subgroups. Recommend measures to enhance health and mitigate potential harms in a health management plan.
The public or other stakeholders are concerned about health effects of the project/policy.	Identify public concerns, facilitate discussion about concerns among stakeholders and assess potential health impacts related to those concerns. Engage stakeholders in identifying measures to enhance health and mitigate potential harms associated with project/policy.
Decision-makers are deciding from among several project/policy options.	List health impacts and characterise their magnitude and distribution in the population. Compare options based on their health impacts and distribution of those among population subgroups.

Roles of the health assessment experts and stakeholders

The case studies illustrate a number of different models for governance and implementation of health assessments with variation in the roles of experts and stakeholder groups.[v] Three main parties may be involved in health assessment: experts in health assessment, stakeholders with specialized technical knowledge (e.g., waste management engineers, planners, and public health practitioners), and community stakeholders (e.g., residents and population sub-groups).[w]

Experts in health assessment usually lead some or all of the assessment tasks: scoping the question, designing the assessment protocol, conducting the assessment and reporting findings. Stakeholders may take on a variety of roles from strictly commenting on results of the assessment to guiding the experts in designing questions and assessment methods or conducting the assessment themselves.

The governance models for quantitative HAs were different from those for HIAs. For quantitative HAs, the process was led by technical experts within government (United Kingdom) or consultant groups (Durham).

HIAs followed two different governance patterns. In the first, an advisory group/steering group comprised of community and specialist stakeholders guided the HIA objectives and protocol and experts performed the assessment (e.g., Wales, Jersey). In the second, a small working group of stakeholders

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[v] The roles of proponents are not discussed here. Proponents provide technical specifications on proposed facilities. In those cases where a proposed facility is undergoing an environmental impact assessment in BC, the proponent is responsible for hiring the consultant to conduct the health assessment. In these cases the specifications of the health assessment are determined through the EIA process as conducted by the Environmental Assessment Office.

[w] These parties may overlap. For example stakeholder with specialised technical knowledge may also have expertise in health assessment.

with specialized knowledge (city staff with expertise in public health and waste management) conducted the assessment using a framework and information about the treatment options provided by a consultant with expertise in HIA (e.g., Toronto). The involvement of public health professionals and community stakeholders in governance of HIAs supports a more fulsome analysis of health impacts.

Public health professionals were instrumental in commissioning and conducting the Toronto HIA, and were involved in governance of a number of other HIAs discussed here. Public health physicians are uniquely trained to assess the health status of populations and to evaluate scientific evidence about health impacts of interventions. They are skilled at examining a range of social determinants of health, and implementing measures to mitigate harm and improve health. Medical health officers and environmental health officers are familiar with the unique populations and issues in communities. Some health authorities have additional staff with the skills to assess a variety of human exposures (i.e. risk assessors) and to consult with communities as to their concerns (i.e. community developers). Health authorities will inevitably be called upon to respond to concerns about any health effects of waste management in their jurisdiction. In addition, public health professionals may request a health assessment for waste management plans under development (e.g. Vancouver case study). If public health professionals are involved at the outset, then these health assessments can be conducted as part of plan rather than as an afterthought. Since public health professionals contribute key skills to HIAs, they should, at a minimum, be involved in scoping and reviewing HIAs.

Community stakeholders have also made important contributions to HIA. One of the key objectives of HIAs in several of these case studies was: to identify community concerns about health impacts of policies, options and projects. Community input is key to addressing community concerns, developing common understanding of risks and benefits of projects, and can prevent unnecessary project delays or cancellation due to outrage. However, HIAs conducted by community groups and others that are outside of the decision-making process risk being ignored as shown in the Cardiff example.

A range of health assessment experts were engaged in health assessments in these case studies and the types of health assessment experts corresponded to the methodologic approach. HHRA was conducted by either consultant groups as part of an environmental impact assessment (Durham) or government agencies with HHRA expertise (United Kingdom). Health impact assessment was commissioned by government agencies and led either by private consultants (e.g., Toronto, Wales), or by a consortium of agencies such as academics, World Health Organization and public health departments (e.g., Jersey, Cardiff).

HIAs only occurred when supported by experts in HIA methods from outside public health departments, either consultants or consortiums. Two consortiums were involved in conducting HIAs in the case studies. The Wales Health Impact Assessment Support Unit (WHIASU) is a university-based, government funded consortium whose goals are: (1) to support effective HIA practice, (2) to provide direct consultation to those performing HIA in Wales and (3) to build research and evidence to improve assessments of policies programs and projects.[69] One of the key roles of the unit is to educate various levels of government about the practice and value of HIA to inform decisions about policies, programs and projects. The Jersey HIA was conducted by a similar group based at the University of Liverpool, International Health Impact Assessment Consortium (IMPACT).[63] Their objectives are to promote HIA in policy and planning through research, consultancy and training and capacity building. Like WHIASU, IMPACT partners with the WHO and health agencies. In contrast, IMPACT also partners with the European Commission and private developers, and it is international rather than domestic and it is self-financing rather than funded by a national government. There is no such consortium to support HIA practice in Canada. A number of groups have compiled HIA resources and case studies (e.g., National Collaborating Centre (NCC) for Healthy Public Policy[70] and NCC Environmental Health.[71]

Proposed Approach to Health Impact Assessment for Waste Management in BC

Key decisions that affect health outcomes are made each phase of decision-making: setting waste policy, deciding among waste treatment and facility options, planning waste facilities and operating them. HIA is a useful process to identify and characterise health impacts arising from physical, social and economic changes associated with waste management projects. HIA may also be instrumental in identifying public concerns about waste management and facilitating discussion with the public. Therefore health impact assessment should be considered in each of these stages by screening to determine whether HIA is necessary. A proposed process for HIA for waste management in BC is shown in Figure 3.

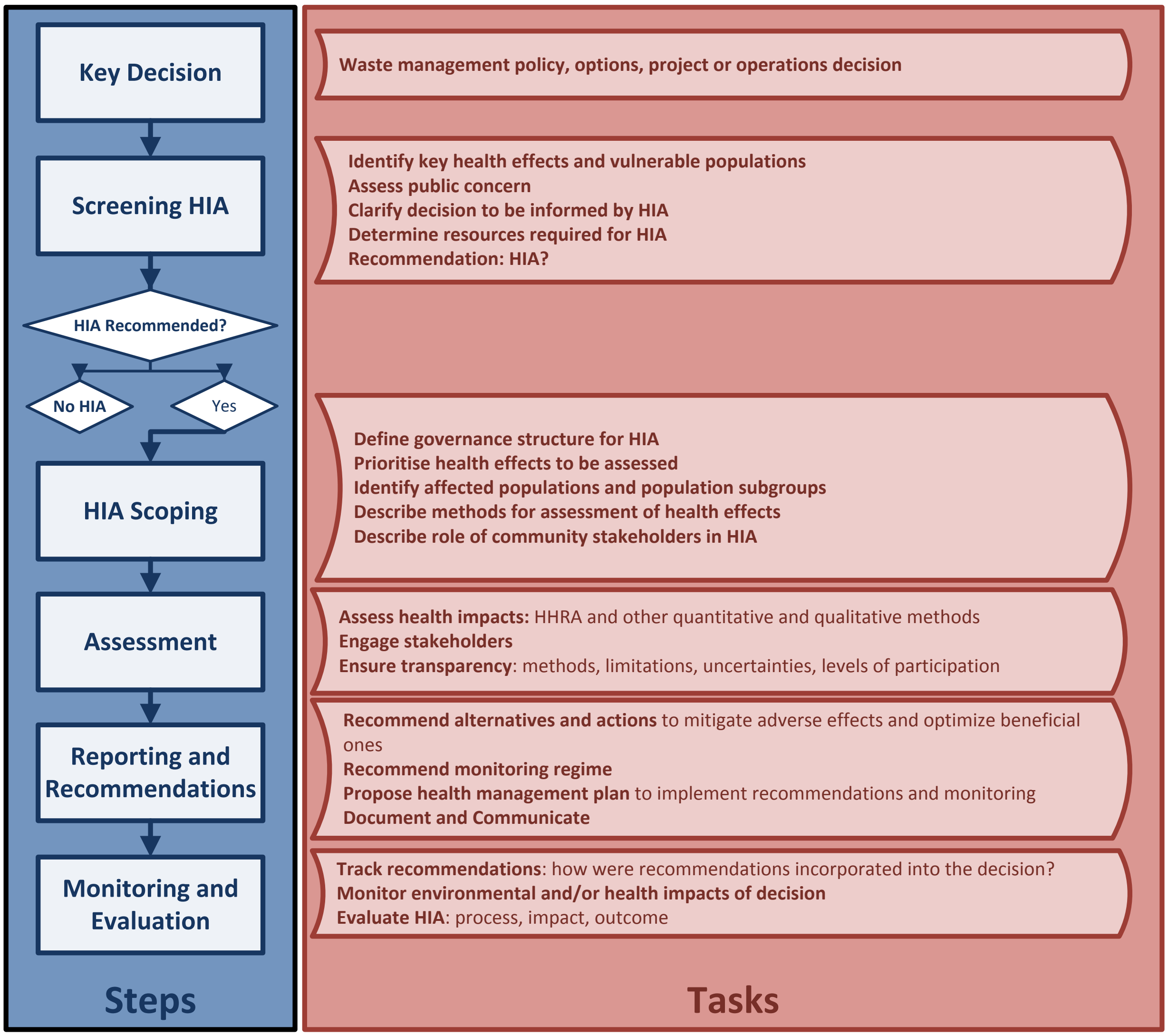


Figure 3.3 *Proposed process for health assessment of waste management projects in BC*

All waste management decisions, whether at the policy, options, plan or operations stage should undergo a "screening HIA" to determine whether health assessment is warranted. This would address a gap in the current process, where only decisions at the plan and operations stages have health assessments, but decisions at the policy and options stages have important health impacts.

At the policy and facility options stages, the screening HIA should determine whether there is important health trade-offs among the options considered, including health outcomes related to changes in the physical environment and those related to changes in the social and economic environments. At the facility plan stage, the screening HIA should determine whether health impact assessment may be adequately addressed by an integrated health and environmental impact assessment process with augmented health assessment (e.g., integrated health and environmental assessment). At the facility operations stage the screening HIA should address whether existing regulations are health protective and whether there is widespread concern among community members and other stakeholders (see Table 3 for examples of situations where HIA is warranted). Screening HIA should be conducted by the agency responsible for the decision, with expert input from public health practitioners. The outcome of the HIA screening will be a decision as to whether an HIA is warranted and what decision it will inform.

If an HIA is warranted then the scope and methodology should be specifically targeted to address a defined decision. The scope, methods and timelines of the HIA would be determined in the scoping phase. The comprehensiveness of HIA may be limited by a number of factors including available resources and the timeframe of the decision-making process. During scoping these limitations should guide planning. In addition, the roles of various agencies should be determined (i.e. Who governs? Who conducts? Who critiques? Who oversees implementation of recommendations?).

The governance structure of HIA should include a range of stakeholders representing public health, community, local government, relevant provincial ministries, and others in order to ensure a balanced approach and to achieve credibility with these stakeholders. HIA is most influential when it is integrated into the policy or planning processes and when HIAs are conducted outside of these processes they risk having their results ignored during decision-making.

It must be clear whether public health agencies are engaged in HIA governance, leading the HIA or providing critical oversight of the process conducted by another group (e.g. consultant, proponent, other government ministry, HIA consortium).

The roles of HIA experts may include:

- Conducting health impact assessments using local health data
- Developing training and capacity-building for health authorities, city waste management engineers, Environmental Assessment Office, various levels of government developing waste management policy and projects
- Providing resources and consultation to health authorities engaged in assessment of health impacts of waste management either through providing critical comments on external assessments or conducting their own assessments

HIA is only possible when (1) there is access to expertise in HIA methods, and (2) sufficient resources are allocated to conducting HIA. HIA is a specific suite of methods that requires expert support. While health departments, waste management departments and other stakeholders are involved in HIA, all of HIAs in our case studies relied on access to HIA expertise from either hired consultants or consortiums with expertise in HIA.

Regardless of which role public health agencies take on, there is a need to develop access to expertise in HIA. No HIA in any of the case studies was conducted by public health agencies without external expertise. Those public health agencies that do conduct HIAs (e.g. Montreal Public Health, San Francisco Public Health) have staff and other resources specifically targeted for this role. BCCDC has conducted a regional scan of risk assessment capacity, and in BC, there is currently not sufficient capacity to conduct or critique HIAs for waste management or other large projects within regional or provincial public health agencies.

Expert consultation could be funded by a variety of mechanisms including targeted allocation of permitting and licensing fees.

Once established, access to expert consultation for HIA should not be limited to waste management issues but should also be used for other environmental policies and projects with potential health effects.

Once the HIA is completed and recommendations have been made, a mechanism is needed to ensure that recommendations are carried out. One of the major criticisms of HIAs conducted to date is that there is little follow-up to assess whether recommendations made in HIAs have been followed. Assessment and monitoring of outcomes following HIA are important for ensuring that health recommendations are followed. In order to achieve this mechanism, options need to be developed by the Ministry of Health, Ministry of the Environment, Environmental Assessment Office and other relevant ministries and agencies. For example, HIA recommendations may be linked to other regulatory processes such as approval of environmental impact assessments, and permitting conducted through the Ministry of Environment.

HIAs are based on best available evidence and best available technologies at the time of the assessment. However, both the state of the evidence of health impacts arising from physical, social and economic factors and the available technologies change over time. Therefore a mechanism should be established to review health impacts of policies and facilities to ensure that they reflect the state of the evidence and use best available pollution control technologies. The approach to conducting regular review can be developed by the province.

Recommendations

The Waste-to-Energy working group of BC Environmental Health Policy Advisory Committee proposes a process for health assessment of waste management in British Columbia.

1. **All waste management decisions should undergo a screening HIA to determine whether HIA should be conducted, and if so, the nature of the HIA.**

All decisions regarding waste management policies, projects and operations should be screened for potential health impacts and, if warranted based on the screening process, then should undergo a health impact assessment. At the policy and facility options stages, the screening HIA should determine whether there are important health trade-offs among the options considered, including health outcomes related to changes in the physical environment and those related to changes in the social and economic environments. At the facility plan stage, the screening HIA should determine whether health impact assessment may be adequately addressed by an integrated health and environmental impact assessment process with augmented health assessment (e.g., integrated health and environmental assessment). At the facility operations stage the screening HIA should address whether existing regulations are health protective and whether there is widespread concern among community members and other stakeholders. Screening HIA should be conducted by the agency responsible for the decision, with expert input from public health practitioners.

2. **When HIAs are conducted, the scope and methodology of the HIA should be designed to address the specific decision that it will inform.**

The scope and methods of the HIA should be suited to the decision that it will inform. Rapid HIA may fit into tight timelines of planning and is valuable for identifying risks for well-established technologies, more comprehensive assessment may be needed when the policy or project has unusual or untested features (e.g., larger scale, closer proximity to populations). Risk assessment methods are valuable for quantifying disease outcomes of emissions, whereas qualitative methods are stronger where the risk relationship is less certain (as for many social determinants of health), for engaging multiple stakeholders, identifying and addressing public concerns.

3. **Community stakeholders should be consulted to identify their concerns about health impacts related to waste disposal policies, proposals and projects. This can be conducted at the level of the province, regional district and/or by proponents as suited to the situation.**

Community consultations are particularly important when community members are concerned about the health implications of a policy, options or project. The case studies demonstrate that when community members are not adequately consulted, there can be increased controversy, acrimony and in some case projects have been delayed or cancelled. In contrast, within HIA community members share in the conversations, and their roles can range from consultant to decision-making. Community consultations should not be restricted to a forum for community members to learn about policies, options or projects. At a minimum, community consultations should be used to elicit and list community concerns that will then be used to help frame the terms of reference for an HIA. This must be conducted early in the HIA during the scoping phase. In addition, community members should be given an opportunity to recommend measures to mitigate potential impacts and these should be considered in the recommendations. In some circumstances, community members may have a much broader role which could include conducting analyses and evaluations of potential health impact and/or other roles in the HIA.

4. Public health agencies and their staff should play a key role in leading or critiquing health impact assessments of policies and projects with environmental health implications, such as waste management.

Public health agencies could either take the lead in conducting health impact assessments or they could provide critical oversight of the HIA process from scoping through assessment and recommendations. Each of these models has been used in other jurisdictions and there are advantages and disadvantages to each. In certain policies and projects it may be more appropriate for health to take the lead, whereas in others the role of critiquing may be more suitable. In either situation, public health professionals, including physicians, environmental health officers and others on their team should provide an analysis of whether to accept the adequacy of a health assessment.

Public health and preventive medicine (PHPM) physicians are trained in assessing health of populations across the range of determinants of health and in the evaluation of scientific evidence including qualitative and quantitative methodologies. Medical health officers should work with public health teams to lead/critique the terms of reference for the health assessment and lead/critique the health assessments. In order to effectively fulfill these roles, public health professionals within health authorities will need to be augmented to include capacity to critique/conduct HIA including understanding HIA and HHRA processes, and will require access to expertise on health impact assessment and project-specific content.

5. The province should invest in building the required expertise and capacity to support the public health role in HIA for environmental health issues, in particular for waste management.

Access to such expertise may be accomplished through a variety of mechanisms including establishing a provincial body with expertise in health agencies (e.g. PHSA, BCCDC) or within the Ministry of Health or the Office of the Provincial Health Officer. Alternatives would be to develop a list of approved consultants for HIA.

The roles of HIA experts may include:

- Conducting health impact assessments using local health data
- Developing training and capacity-building for health authorities, city waste management engineers, Environmental Assessment Office, various levels of government developing waste management policy and projects
- Providing resources and consultation to health authorities engaged in assessment of health impacts of waste management either through providing critical comments on external assessments or conducting their own assessments

Expert consultation could be funded by a variety of mechanisms including targeted allocation of permitting and licensing fees.

Once established, access to expert consultation for HIA should not be limited to waste management issues but should also be used for other environmental policies and projects with potential health effects.

6. The province should establish a mechanism to ensuring that recommendations from HIA are carried out.

One of the major criticisms of HIAs conducted to date is that there is little follow-up to assess whether recommendations made in HIAs have been followed. Assessment and monitoring of outcomes following HIA are important for ensuring that health recommendations are followed. In order to achieve this mechanism, options need to be developed by the Ministry of Health, Ministry of the Environment, Environmental Assessment Office and other relevant ministries and agencies. For example, HIA recommendations may be linked to other regulatory processes such as approval of environmental impact assessments, and permitting conducted through the Ministry of Environment.

7. Waste management policies and facilities should be reviewed on a regular basis to ensure that the mitigation measures reflect the latest evidence and available technologies. This can be conducted at the level of the province, regional district and/or by proponents as suited to the situation.

HIAs are based on best available evidence and best available technologies at the time of the assessment. However, both the state of the evidence of health impacts arising from physical, social and economic factors and the available technologies change over time. Therefore a mechanism should be established to review health impacts of policies and facilities to ensure that they reflect the state of the evidence and use best available pollution control technologies. The approach to conducting regular review can be developed by the province.

8. Human health risk assessment (HHRA) methods should be used to assess health impacts of all new MSWI and all major upgrades to existing MSW thermal treatment facilities.

The epidemiologic literature on incineration is not directly generalizable to modern incinerators. Given that emissions from thermal treatment facilities in 2012 are well below those reported in epidemiologic literature, published risk estimates are not relevant to modern incinerators. Our evidence review identified three major knowledge gaps: (1) absence of epidemiologic studies on the health effects of modern MSWI, (2) absence of epidemiologic studies of health effects associated with pyrolysis and gasification facilities, and (3) absence of emissions inventories for pollutants other than heavy metals and dioxins (e.g., ultrafines, nanoparticles). HHRA should be based on known toxicologic hazards of emitted pollutants rather than published risk estimates from the epidemiologic literature. If new studies are published that provide relevant risk estimates, then this recommendation will need to be re-examined.

At each of the decision-making stages, HHRA should be conducted for specific scenarios. In the options stage HHRA should be conducted as part of the regional district assessment of options. In the plan stage HHRA should be conducted as part of the EIA. In the operations stage HHRA should be conducted by the Ministry of Environment in their WDA process. As upgrades of facilities are considered by Ministry of Environment, or changes to waste management factors (e.g. waste streams, volume, et cetera) by Regional Districts, then HHRA should be considered.

9. HHRAs should address the specific characteristics of the proposed facility thermal treatment technology, pollution control systems and transportation routes.

The following factors should be considered in the HHRA:

- Air emissions of facility and waste transport
- Air, soil and water concentrations at receptors
- Exposures related to handling and disposal of solid wastes
- Exposures of human receptors along transportation routes
- Exposures to other physical hazards (e.g. noise)
- Other factors identified by public health professionals, stakeholders or community members as appropriate

10. Thermal treatment facilities should use the best available pollution control technology and upgrade this technology as improvements are available in order to reduce emissions to levels at or below regulatory guidelines. This can be achieved during permitting by BC Ministry of Environment.

The committee concludes that risk estimates from thermal treatment facilities in the published literature involved MSWI with dioxin emissions well above current regulatory standards (80 pg/m^3 TEQ) and are therefore not applicable to modern incinerators that operate within these standards. However, a number of uncertainties remain and

Thermal treatment employs technologies for thermal treatment, air pollution control and transportation air pollution control that are developing over time. The types of by-products that are produced (e.g. air emissions, wastewater effluents, solid waste residue and solid wastes from air pollution control devices) will vary by facility and as new technologies are developed. We recognise that achieving the lowest possible emissions levels is optimal for health, and that regular upgrades to pollution control technologies are one mechanism to achieve this.

11. HHRA should model exposures and health outcomes for vulnerable populations as well as the general public.

Certain populations such as the elderly, children, and developing fetuses are more vulnerable to some adverse health effects from exposure to contaminants. Public health practitioners are knowledgeable about the vulnerable populations within their jurisdictions. Therefore, the list of vulnerable populations should be determined based on the best available evidence and in consultation with local public health practitioners.

Appendix A: Metro Vancouver Waste-to-Energy Facility Case Study

Figure A.1 *Metro Vancouver WTEF facility with line that carries steam to adjacent paper recycling facility*

Overview

Metro Vancouver's Waste-to-Energy Facility (MV WTEF), located in the commercial/industrial area of South Burnaby, opened in 1988. It is owned by Metro Vancouver and is currently operated and maintained by Covanta Burnaby Renewable Energy Inc. The facility manages approximately 20% of the Lower Mainland's waste, mainly from Burnaby, New Westminster, and the North Shore.[72]

Technology, Inputs, and Outputs

The MV WTEF manages Municipal Solid Waste (MSW). The facility has three mass burn processing lines; each one processes approximately 850 tonnes of waste per day (Table 6). Annually, 285,000 tonnes of MSW are turned into 940,000 tonnes of steam and 132 GWh of electricity[72]; daily outputs include 130 tonnes of bottom ash and 30 tonnes of fly ash (Table 6). Figure 7 depicts the operation of a processing line. In 2003, a turbo generator was installed that uses the steam to produce electricity. In 2006, a $7 million upgrade was completed to increase the amount of heat recovered from waste and, therefore, the amount of electricity produced. The steam is sold to a paper recycling facility, while electricity is sold to BC Hydro.

Table A.1 *MV WTEF summary*[73]

Energy-from-Waste System	Three Martin mass burn boilers
Boiler Design	525 psig/662°F super-heater outlet conditions
Waste Capacity	850 tonnes per day
Steam Customer	Noramac Paper
Average daily amount of steam sold	600 tonnes
Electricity customer	British Columbia Hydro
Average daily amount of electricity sold	400 megawatt-hours

Energy-from-Waste System	Three Martin mass burn boilers
Other average daily outputs	130 tonnes of bottom ash (used in road building and landfill cover) 30 tonnes of fly ash (disposed at landfill) 25 tonnes of metal (recycled into steel)
Pollution controls	Lime – to control acid gas emissions Ammonia – to control nitrogen oxide emissions Activated carbon – to control mercury emissions Phosphoric acid – to stabilize metals in fly ash and bottom ash
Air Pollution Control Equipment	Flakt Dry Absorption Reactor Flakt Pulse Jet Baghouse

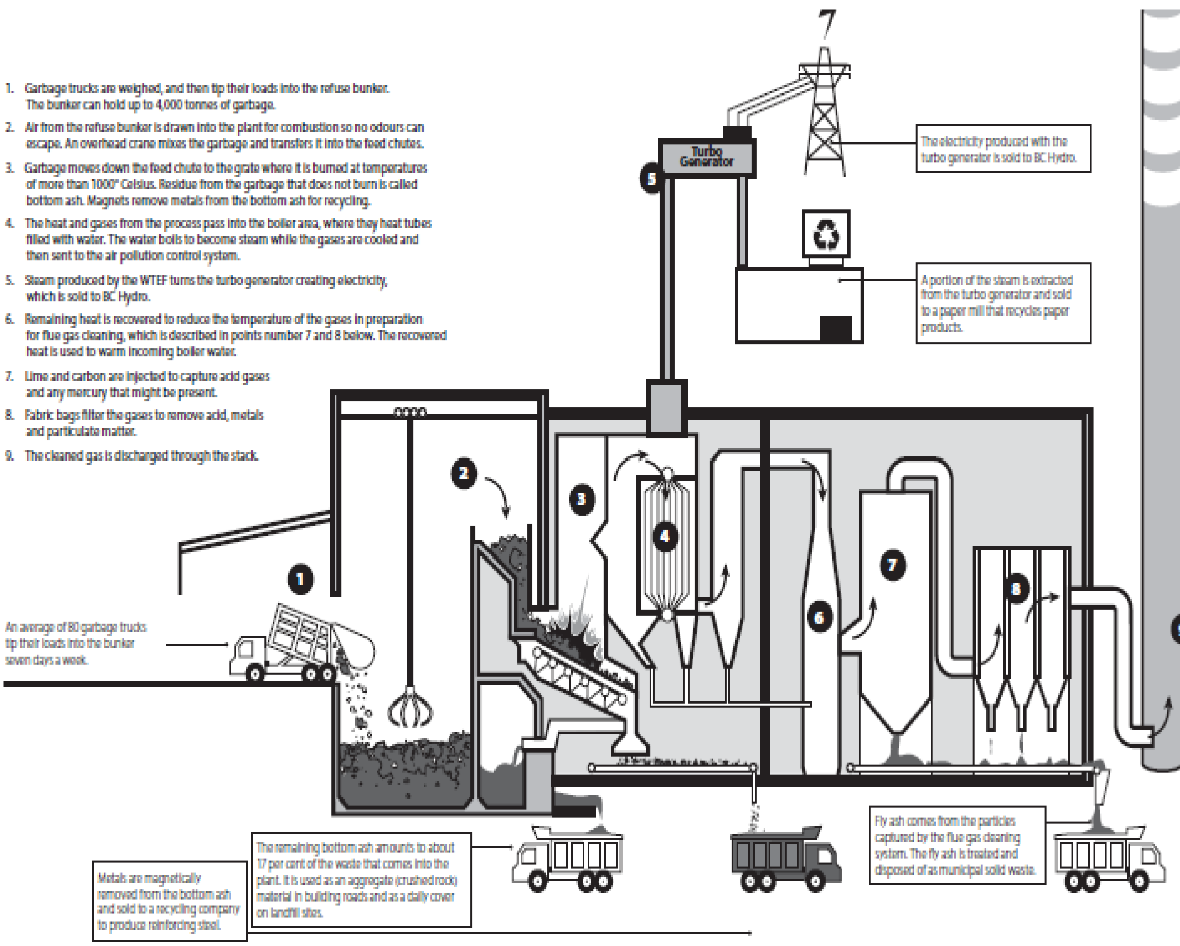


Figure A.2 *Operation of a processing line*[72]

The MV WTEF only processes MSW, no hazardous waste is accepted. The facility is mass burn so there is no pre-processing or sorting of material prior to treatment. Ferrous metal is recovered from the ash. Table 7 outlines an example of the composition of waste at the MV WTEF and Table 8 presents the facility waste restrictions.

Table A.2 *Composition by primary category of waste sorted at Burnaby WTEF, July 1998*[6]

Category	% of Total (SD)
Organics	37.4 (11.1)
Paper	32.3 (10.6)
Plastic	13.3 (5.4)
Household Hygiene	3.8 (3.3)
Metals	3.4 (1.5)
Glass	3.1 (2.3)
Inorganic	2.9 (3.8)
Household Hazardous	2.2 (2.1)
Fines	1.2 (1.7)
Small Appliances	0.5 (1.4)

Table A.3 *Waste restrictions*

Unacceptable	Restricted
• Hazardous wastes • Flammable or explosive materials • Hazardous or reactive chemicals – solid, liquid or gas • Liquids, sludge or waste with greater than 50% moisture content • Hot or burning loads • Large, bulky or heavy articles; over 1 metre or 100 kg • Cylindrical drums (greater than 40 gallons), gas cylinders • Gypsum • Large quantities of sulphur containing materials • Lead acid batteries • All items which contain large amounts of heavy metals • Hospital “sharps” • Pathological and biological waste (including dead animal parts) • Tight-head barrels (non-removable tops) • Commercial quantities of demolition waste, non-combustible construction material • Asbestos • Radioactive material • Strong, offensive smelling loads • Wood larger than 100 mm diameter, or equivalent • Large quantities metal strapping, cables, ropes, wires, hoses, fish nets • Automobile engines, transmissions, major parts of motor vehicles • Corrugated cardboard, newsprint, and office paper • Blue box recyclables, beverage containers (except milk) • Waste oil or petroleum by-products, oil filters, oil containers • Vehicle tires • Yard trimmings • Pharmaceuticals • Electronic waste (e.g., PCs, monitors, TV’s, printers, faxes)	• Oily waste from spill clean-up - requires prior permission • Dusty materials - requires prior permission and “identification before dumping” • Fibreglass insulation, must be double bagged • Pesticide containers must have one end of the container removed and triple-rinsed • Containers for chemicals, paints, resins, etc. are acceptable if cleaned or residue solidified • Fill (e.g., sand gravel, asphalt, rock, concrete) must be less than ½ cubic metre per load • Waste that requires special preparation or handling

Pollution Control

Each line has a dry lime injection reactor that removes sulfur dioxide, hydrochloric acid, other acid gases, and a fabric filter baghouse that removes lime solids and fly ash. Activated carbon is injected with the lime to control mercury emissions. An aqueous ammonia injection system was installed in September 1996 and is injected to control nitrogen oxide emissions. Magnets remove ferrous metals from bottom ash. Bottom ash is used in building roads and as a cover on landfill sites. Fly ash is treated and disposed of as municipal waste in a landfill. Phosphoric acid is added to stabilize metals in the fly ash and bottom ash.

Air Quality

Generally, air pollutant emissions from the stacks of WTE facilities fall into 5 categories:

- Particulate matter (including a number of heavy metals, such as lead and cadmium);
- Acid gases (which include HCl, SOx, H_2SO_4 and HF);
- Heavy metals (e.g., mercury);
- Products of incomplete combustion, including carbon monoxide, and such toxic organic compounds as dioxins and furans and their precursors chlorobenzenes and chlorophenols;
- Oxides of Nitrogen (NO_2, NO).

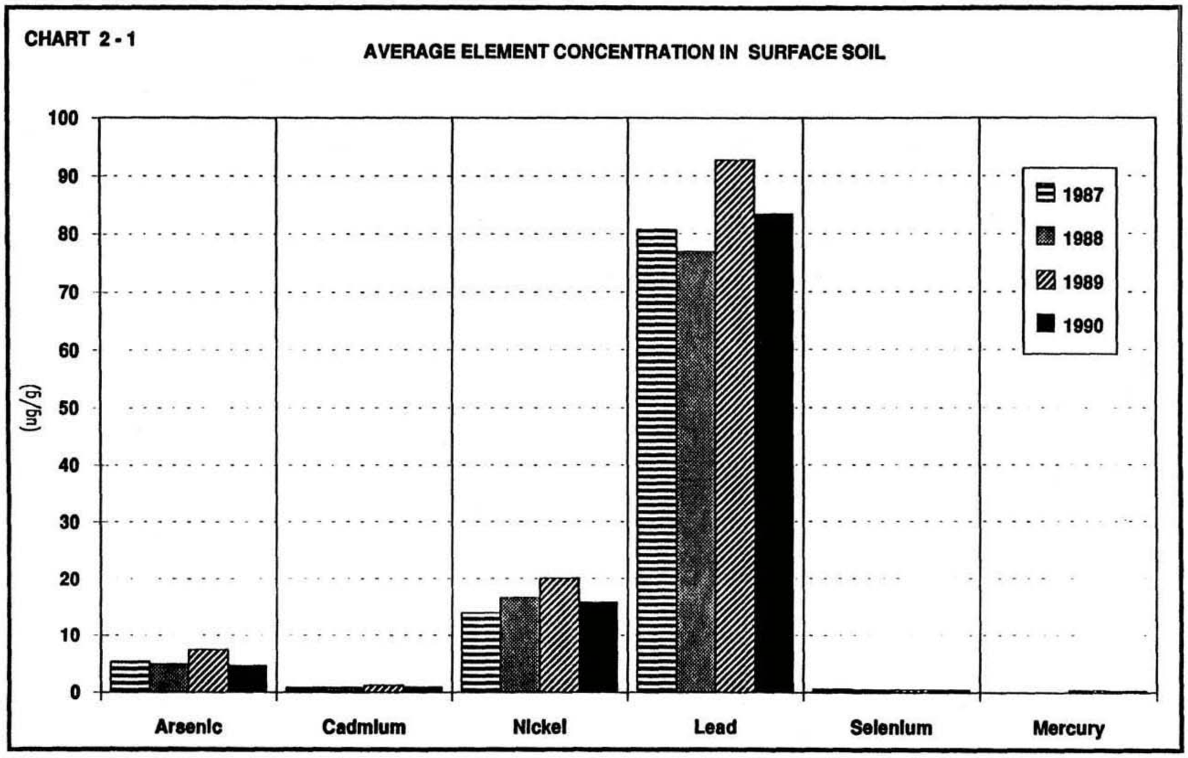
See Table 10 for Metro Vancouver's figures presenting the levels of various compounds with corresponding regulatory levels between 1998 and 2009.[74] According to these figures, none of these compounds are currently above the regulatory level. Nitrogen oxides were elevated between 1988 and 1994/1995, and 'class 1 metals' (cadmium, mercury, thallium) were slightly elevated in 1999, but have since decreased.

Soil and Vegetation Monitoring

As part of the Greater Vancouver Regional District's (GVRD) ambient monitoring program, monitoring of the impact of the MV WTEF on the neighbouring area's soils and vegetation was conducted. Incinerator pre-operational monitoring was conducted in 1987 to develop background levels and then samples were collected for 3 consecutive years following the start-up of the incinerator in 1988.[74]

Soil and vegetation samples were collected from eight monitoring sites in Delta, Richmond, and Burnaby; selected in the projected maximum fall out areas and to reflect both the diversity of land uses and native ecosystem in the vicinity of the incinerator. There were six agricultural monitoring sites and two non-agricultural sites, representing native ecosystems, were added in 1988. Soil and vegetation matter were analyzed for six elements: [arsenic (As), cadmium (Cd), nickel (Ni), lead (Pb), selenium (Se), and mercury (Hg)] (see Table 9) as well as polycyclic aromatic hydrocarbons (PAHs); vegetation samples were also analyzed for fluoride (F) and sulphur (S).

Table A.4 *Average element concentration in surface soil*[75]



The GVRD (1992) report concluded there was no evidence that the MV WTEF emissions had any adverse impact on soil and vegetation trace element or PAH levels. Cadmium at a particular site and nickel at another site were elevated, but it is suggested that the probable cause is something other than the incinerator operation[75] (see Table 10 for details). It does not appear that subsequent soil and vegetation monitoring continued, therefore it is not possible to assess a long-term trend.

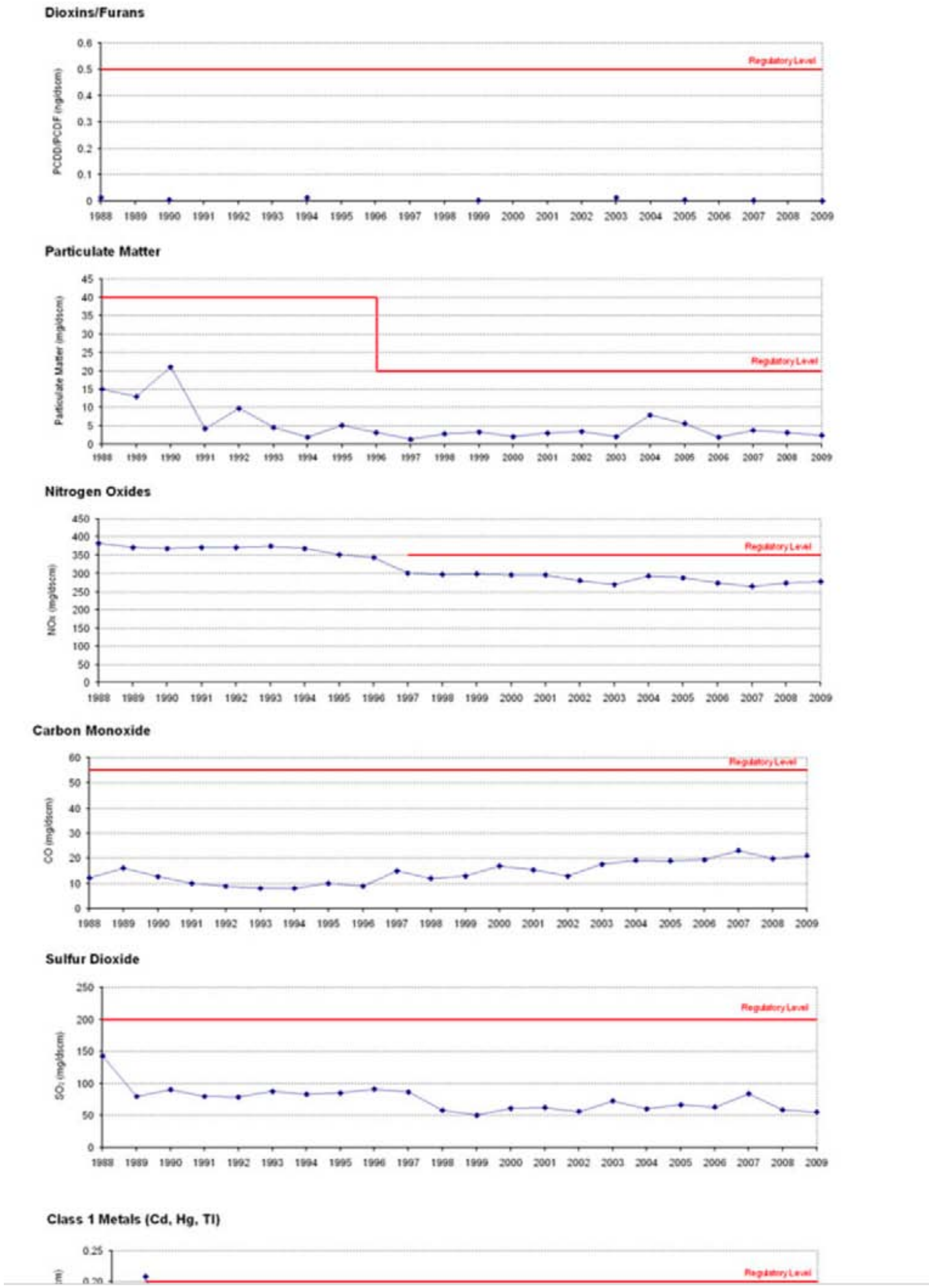
Table A.5 *Information on elements sampled in soil and vegetation (1987 – 1990)*[12]

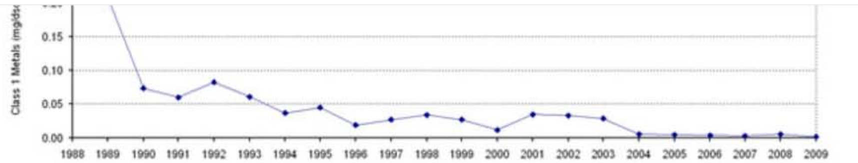
Elements	Soil and Vegetation Sampling
Arsenic	Natural background level for arsenic in soil: 5 µg/g. Some monitoring sites slightly exceeded this background level, but the report concludes there is no evidence that arsenic has accumulated in surface soil during incinerator operation (note that levels in 1990 were below the 1987 level at 5/6 agricultural sites and below the 1988 level at both non-agricultural sites).
Cadmium	Natural background level: 1 µg/g. in all but one site; most of the time, annual average concentration of cadmium in soils remained below the natural background level. In 1989, one site's concentration approached the proposed remediation level of 5 µg/g. In 1990, the concentration decreased to levels very similar to those of pre-incinerator start-up measured in 1987. The cadmium concentration in soils at all monitoring sites in 1990 was lower than in one or more of the previous sampling years. The report concludes that a relationship cannot be drawn between incinerator operation and measured concentrations in the soil.
Lead	The highest lead concentration (328 µg/g) in a single sample occurred in 1990 at a particular site; other samples from the same site ranged from 63 to 120 µg/g. After removing this sample from the data bank, the average value for the site was 92 µg/g; following a similar pattern observed at the other sampling sites. In 1990, the lead level decreased below 1989 levels and at several sites even went below the 1988 level. The site with the highest lead level still had concentrations less than half of the proposed objective for soil remediation in BC. The presence of leaded gasoline is discussed as a factor.
Mercury	Annual average mercury concentrations in 1990 varied from 0.1 to 0.65 µg/g. Of the 8 sampling sites, annual average values decreased at 5 sites and increased at 3 other sites. In all cases, mercury levels are less than 1/3 of the proposed remediation objective for mercury. Note that data for mercury concentration in surface soil, analyzed by the cold vapour mercury method, is available for 1989 and 1990 only.
Nickel	Nickel concentration in surface soil increased in 1988 and 1989, but in 1990 the concentration decreased (at 5 sites, it even decreased below the 1988 level). In all but 2 sites, nickel levels remained below the natural background level. All annual averages were less than half the proposed remediation objective.
Selenium	Generally, concentrations of selenium in soils at all monitoring sites were close to or below natural background levels. Concentrations in surface soils decreased each year since 1987.

Environmental (EIA) and Health Impact (HIA) Assessments

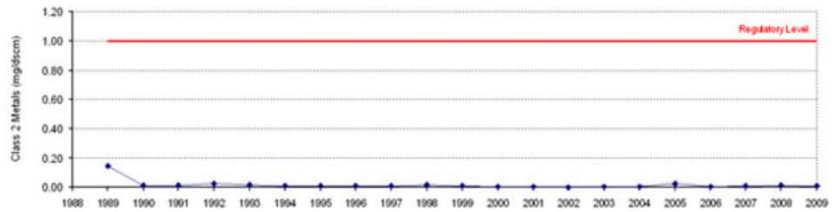
There is no record of HIA being conducted. The BC environmental impact assessment legislation was not in place at the time of the MV WTEF start-up. Beyond the air emissions and early soil studies, there is no record of EIA.

Table A.6 *Air Emissions Metro Vancouver waste-to-energy facility summary of air emissions 1998-2009 (Metro Vancouver WTEF performance data)*

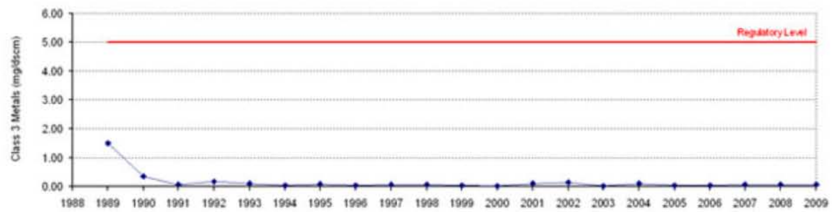




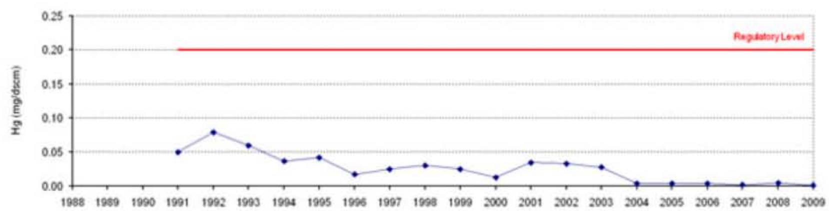
Class 2 Metals (As, Co, Ni, Se, Te)



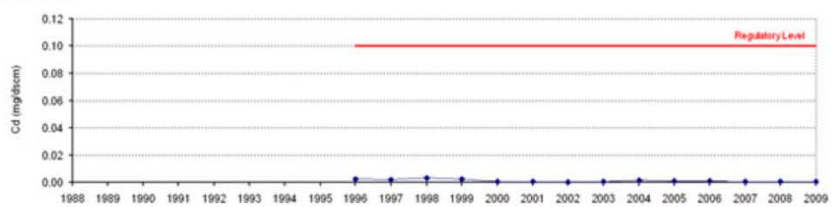
Class 3 Metals (Sb, Pb, Cr, Cu, Mn, V, Zn)



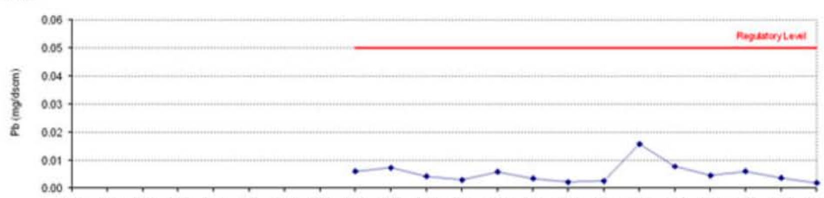
Mercury



Cadmium



Lead



Glossary

Baghouse – Fabric filters used to reduce emissions of solid particulate matter (including carbonaceous and metallic particles and condensed matter, such as metals, organics, and acids). In a **pulse jet baghouse**, the particulate matter accumulates on the outside of bags in which stiffeners are used to retain the shape. The particulates drop off the outside of the bags when a pulse of air is forced into the bag.[76]

Bottom ash – Solid waste that is not completely burned on the grate.

Dscm – Dry standard cubic meter

***Fly** ash* – Solid and condensable particulate matter which leaves the furnace suspended in the combustion gases and are subsequently collected in emission control devices.

Mass burn processing – Mass burn plants are designed to burn unprocessed solid waste (waste processing is minimal, only involves mixing and drying of wastes). This is distinguished from refuse derived fuel (RDF) plants which have waste pre-processing and sorting into resource streams.[76]

Municipal solid waste – As of 1992, the *Waste Management Act* defines MSW to mean: (a) refuse that originates from residential, commercial, institutional, demolition, land clearing or construction sources, or (b) refuse specified by a manager to be included in waste management. The definition of MSW implicitly excludes sewage sludge, agricultural waste, and industrial wood waste.[77]

Scrubbers – used to decrease acid gas emissions and increase condensation of metals and organics. There are a variety of designs. An alkaline reagent such as lime is injected for absorption and neutralization. In dry injection scrubbers, the alkaline reagent is used without water, producing a dry salty residue containing a combination of alkaline and acidic agents. In wet-dry or spray-dry absorbers, both water and alkaline reagent are injected; the reagent enters the scrubber in wet (slurry) form and exits as a dry residue, with the water having been evaporated in the scrubber.

Appendix B: Summary of reviews of health effects of municipal solid waste incinerators (MSWI) from the peer-reviewed and non-peer-reviewed literature

Objective	Method	No. of studies and dates	Conclusions	Appraisal
Peer Reviewed Systematic Literature				
Franchini, M., M. Rial, et al. "Health effects of exposure to waste incinerator emissions: A review of epidemiological studies." Annali dell'Istituto Superiore di Sanita. 2004 **40**(1): 101-115.[26]				
To present a review of the major epidemiological studies published from 1987 to 2003 on health effects in populations living in the neighbourhood of waste incinerators	Systematic search using Medline and several combinations of relevant key words. In addition, articles were traced through references in relevant papers and publications of the UK Institute for Environment and Health, the US National Academy of Sciences and Greenpeace.	46 papers: 32 in populations residing near incinerators, 11 on occupational exposure, 2 on environment and occupation and 1 survey on the relationship between high cancer death rate and environmental concentration of dioxin analogues. Papers published between 1987 -2003.	Significant results: • Lung cancer • Non-Hodgkin's lymphoma • Soft tissue sarcomas • Childhood cancers Contradictory results: • Cancer of the larynx • Liver cancer Inconclusive: • Non-carcinogen pathologies (in particular acute and chronic respiratory disease) • Congenital malformations	Moderate search methodology, weak assessment of the evidence. No quality assessment of studies. Discussion of health effects is rather general, although overview table is clear. Overall weaknesses and strengths of epidemiological studies are described, but not for individual studies.
Hu SW, Shy CM. Health effects of waste incineration: a review of epidemiologic studies. J Air Waste Manag Assoc. 2001 Jul;51(7):1100-9.[27]				
To review previous epidemiologic studies of health effects of waste incineration.	A keyword search mapped to the subject headings for incinerator and incineration, with an 'explode' option to identify all incinerator-related studies indexed in Medline from 1985-early 1999. Examination of titles and abstracts to choose all epidemiologic studies of health effects or human body chemical levels. References cited by reviews were checked.	11 studies on residents of communities with a waste incinerator, 11 studies on incinerator workers (22 total), published between 1989 -1998.	Residents: • Reproductive effects: higher twinning, lower male-to-female ratios of births, no association with cleft lip and palate malformation. • Cancer: conflicting evidence for lung, mortality, laryngeal cancers • Respiratory symptoms: no relation Incinerator workers: • Higher frequency of urinary mutagens and promutagens, increased blood levels of certain organic compounds and some heavy metals • Excessive deaths from gastric cancer, non-significant increase in esophagal cancer mortality, lung cancer mortality conflicting • Excessive deaths from ischaemic heart disease • Higher prevalence of hypertension • No adverse effects on lung function	Methodology moderate, no hard conclusions, but explanations for the sources of inconsistency. No quality assessment of the studies, although some shortcomings are highlighted (most studies did not control for smoking, no information available on type of waste burned and lack of exposure data). Study designs are not well described.

Objective	Method	No. of studies and dates	Conclusions	Appraisal
Peer Reviewed Systematic Literature				
Porta D, Milani S, Lazzarino A, Perucci CA, Forastiere F. Systematic review of epidemiological studies on health effects associated with management of solid waste. Environ Health. 2009;8(60).[13]				
Systematic review of epidemiologic literature on the health effects in the vicinity of landfills and incinerators and among workers at waste processing plants to derive usable excess risk estimates for health impact assessment	Explicit search strategy using literature databases, and tracing references from these papers, previous reviews and UK Department for Environment, Food and Rural Affairs review (2004). Articles reviewed by three independent reviewers and evaluated as inadequate, limited or sufficient based on criteria from the International Agency for Research on Cancer (IARC).	49 papers: 32 general population and 17 occupational, published between 1983-2008	Inadequate evidence for health associations between incinerators and: • Cancer o Larynx o Kidney o Bladder o Childhood cancer • Birth defects o Total o Neural tube o Abdominal wall o Gastrointestinal o Low birth weight o Respiratory symptoms or disease Limited evidence: • Cancer o Stomach o Colorectal o Liver o Lung o Soft tissue sarcoma o NHL • Birth defects o Orofacial o Genitourinary Sufficient evidence was not found for any health effects associated with incinerators. Inadequate evidence for health associations between landfills and most health effects listed above. Exception is limited effects for: total birth defects, neural tube defects, low birth weight. No health outcomes had sufficient evidence.	Comprehensive review with moderately strong methodology. Appraisal of evidence based on consistent solid criteria. Highlights the limitations of the available literature.

Aim/objective	No. of studies and dates	Discussion/conclusions	Appraisal
Peer Reviewed Non-Systematic Literature			
Giusti L. A review of waste management practices and their impact on human health. Waste Manag. 2009;29(8):2227-39.[28]			
To summarize the most recent information on waste increases and waste disposal in the world, de EU, in OECD countries and in some developing countries and to evaluate the epidemiological evidence of direct and indirect impact of waste management activities on health.	Total: 108 (including general references on the field of epidemiology), published between 1978 - 2009	• The existing epidemiological evidence is controversial. • Confounding factors have not been adequately controlled in many studies. • Incineration is often reported to be associated with an increased risk of NHL and sarcomas • Few studies on new-generation incinerators • There is a need to set up well-designed epidemiological studies capable of giving evidence of the effects of exposure to low levels of potentially hazardous substances. • It is important to consider the benefits to public health that derive from disposing waste in state-of-the-art facilities	Overview of waste management practices, but not an analysis of the evidence of health effects related to WI.
Thompson J, Anthony H. The health effects of waste incinerators. J Nutrit Environ Med. 2005;15(2-3):115-56.[29] British Society for Ecological Medicine. The health effects of waste incinerators: 4th Report of the British Society for Ecological Medicine. London, UK: BSEM; 2008.[30]			
To look at all the evidence [regarding the danger of waste incinerators] and to come to a balanced view about future dangers that would be associated with the next generation of waste incinerators	Total: 329 (including references on air pollutants, toxicology of chemicals and physiological mechanisms of suspected health effects) 20 epi studies on incineration published between1989-2007	Health effects: • Higher rates of adult and childhood cancers and birth defects around incinerators • Incinerators emit toxic heavy metals and endocrine disrupting chemicals • Fine PM contributes to heart disease, lung cancer, other diseases and an increase in mortality • Reason for concern for long-term (genetic) effects of incinerator emissions on foetus, infants and future generations Other conclusions: • Modern incinerators produce fly ash which is far more toxic than in the past, containing large quantities of dioxin-rich material, which can leach into the environment when land filled • Waste incineration is unjust because its maximum toxic impact is on the most vulnerable members of our society: the unborn child, children, the poor and the chemically sensitive.	Not an analysis of the available evidence, but a (subjective) description of studies on the relation between air pollution and health effects in general, and on how these effects can be extrapolated to incinerators. (and no studies are included that found no effects or that were inconclusive). No assessment of the quality of the evidence. No description of search criteria. No description of strengths and limitations of the studies. The 2008 report is an update and is more elaborate, but almost identical to the 2005 one.

Aim/objective	No. of studies and dates	Discussion/conclusions	Appraisal
Non Peer-Reviewed Literature			
Allsopp M, Costner P, Johnston P. Incineration and human health. State of knowledge of the impacts of waste incinerators on human health. Environ Sci Pollut Res Int. 2001;8(2):141-5.[31]			
To draw together scientific findings on incinerator or releases and their impacts on human health.	19 papers published between 1984-2000 (Source: HPS report)	A broad range of health effects have been associated with living near to incinerators as well as with working at these installations. Such effects include cancer (among both children and adults) adverse impacts on the respiratory system, heart disease, immune system effects, increased allergies and congenital abnormalities.	Not a systematic review. Most studies used are outdated (>15 years old), not clear how the search was perfomed, conclusion does not follow from evidence presented.
Committee on Carcinogenicity of Chemicals in Food Consumer Products and the Environment. Cancer incidence near municipal solid waste incinerators in Great Britain. COC statement COC/00/S1 - March 2000. United Kingdom. Oxon, UK: COC; 2000.[11] Committee on Carcinogenicity of Chemicals in Food Consumer Products and the Environment. Review of cancer incidence near municipal solid waste incinerators. COC statement COC/09/S2 - March 2000. United Kingdom. Oxon, UK: COC; 2009.[12]			
Statement COC/00/S1: To provide background information on municipal solid waste incineration in the UK, to review the Small Area Health Statistics Unit (SAHSU) of cancer incidence near to municipal solid waste incinerators and conclusions reached by the committee regarding the risk of cancer associated with living near to municipal incinerators. Statement COC/09/S2: Review of reports and epidemiological investigations (n=6) of cancer incidence near to MSWIs published since 2000	First statement: 8 studies published between1991 -2000 Second statement: total of 15 references, including 7 additional epi studies published between 2000-2008	Statement COC/00/S1: "It is not possible to conclude that the small increase in primary liver cancer is due to emissions of pollutants from incinerators, as residential socio-economic confounding cannot be excluded. An excess of all cancers, stomach, lung and colorectal cancers was due to socio-economic confounding and was not associated with emissions from incinerators. Any potential risk of cancer due to residency (for periods in excess of 10 years) near to municipal solid waste incinerators was exceedingly low and probably not measurable by the modern epidemiological techniques. At the present time, there is no need for any further epidemiological investigations of cancer incidence near municipal solid waste incinerators." (p. 4) Statement COC/09/S2 Limited evidence: • STS and living near incinerators (no adjustments for confounding) Some evidence: • STS and residence near to incinerators in the past (with far higher emissions) Overall conclusion: "no need to change the advice given in the 2000 statement but the situations should be kept under review."	Good description of histological review of cancer cases, good description of studies and their weaknesses and strengths, although it's not clear how the papers were retrieved. Does not review all the evidence

Aim/objective	No. of studies and dates	Discussion/conclusions	Appraisal
Department for Environment Food and Rural Affairs. Review of environmental and health effects of waste management: municipal solid waste and similar wastes. London, UK: DEFRA; 2004.[8]			
A review of published literature on the health and environmental effects of MSW management. A compilation of information on emissions from MSW management facilities to air, land, groundwater, surface water and sewer. Human health risk assessment is based on emissions to the environment. Each study was assessed using a critical appraisal according to study type, sample size, exposure definition and measurement, outcome and control for confounding factors.	23 epidemiological studies and 4 reviews on waste incineration and health, published between 1988- 2003	Health effects in people living near waste management facilities were either generally not apparent, or the evidence was not consistent or convincing. Benefits of waste management and collection are outlined as well.	Very detailed report on waste management and human health risk assessment. Search methodology is moderate and not very clear, relevant information hard to find. Good assessment criteria. Puts conclusions in context and outlines benefits of waste management and collection for human health and the environment.
Health Protection Agency. The impact on health of emissions to air from municipal waste incinerators London, UK: HPA; 2009.[32]			
To review research undertaken to examine the suggested links between emissions from municipal waste incinerators and effects on health.	Total: 30, including 7 epidemiological studies published between 1996-2008	"Modern, well-managed incinerators make only a small contribution to local concentrations of air pollutants. It is possible that such small additions could have an impact on health but such effects, if they exist, are likely to be very small and not detectable." (p. 11)	Not a comprehensive review of the evidence, but some useful background information on particles and carcinogens. Summarizes COC statements and repeats their conclusions.
Health Protection Scotland. HPS Briefing note. Incineration of waste and reported human health effects. Glasgow, UK: National Services Scotland, Health Protection Scotland; 2009.[9] Health Protection Scotland. Incineration of waste and reported human health effects. Glasgow: National Services Scotland, Health Protection Scotland; 2009.[10]			
The Scottish Environment protection agency requested a report from HPS on the evidence of human health effects associated with incineration to complement their issue of updated guidance on incineration.	5 non-peer reviewed reports, 5 systematic reviews published between 1990-2004, 8 primary papers not included in the reviews	Evidence for an association with adverse health effects is inconsistent and inconclusive. There may have been an association between emissions (particularly dioxins) in the past from industrial, clinical and municipal waste incinerators and some forms of cancer, before more stringent regulatory requirements were implemented.	Comprehensive report with solid search criteria and good discussion of the available evidence.

Aim/objective	No. of studies and dates	Discussion/conclusions	Appraisal
National Research Council, Committee on Health Effects of Waste Incineration, Board on Environmental Studies and Toxicology, Commission on Life Sciences. Waste incineration and public health. Washington, DC: National Academy Press; 2000.[7]			
To assess relationships between waste incineration and human health and to consider specific issues related to the incineration of hazardous waste, municipal solid waste and medical waste. The NRC established the Committee on Health Effects of Waste Incineration to assess relationships between human health and incineration of hazardous waste, municipal solid waste and medical waste. Tools that are used to evaluate the potential for health effects from incineration facilities are environmental epidemiology and risk assessment.	19 references, published between 1948-1999 (Source: HPS report)	The evidence for health effects near incinerators is inconsistent or inconclusive. Workers at MSWIs are at a much higher risk than individual residents.	Comprehensive overview of waste incineration and public health. Method is not described, but the HPS reports date ranges and number of papers included in the NRC book.
Pheby D, Grey M, Giusti L, Saffron L, (South West Public Health Observatory Project Team). Waste management and public health: the state of the evidence: A review of the epidemiological research into the impact of waste management activities on health: Prepared for the South West Public Health Observatory and the Centre for Research in Environmental Systems, Pollution and Remediation University of the West of England; 2002.[33]			
To provide an overview of the health impacts of different methods of waste management methods so as to inform public health input into the waste management regulatory system. Assessment of the evidence: convincing, probable, possible, insufficient.	3 reviews, 24 discussion papers, 51 primary research papers (14 of which occupational). Papers published 1982-2002, reviews published 1992-2002	General conclusion: • The data collected on waste management are not detailed enough to make meaningful assessments of potential health impacts that might arise from waste management practices. • Specific for incineration: insufficient evidence for any health outcomes	Elaborate literature research, good assessment method of the evidence, but no description of the studies. Conclusions are very general and cannot be drawn from the rest of the report.

Appendix C: Summary of peer-reviewed primary studies of health effects of municipal solid waste incinerators (MSWI). (* asterisk denotes statistically significant finding of health effect)

Objective	Method	Type of facility and dates of operation	Population size and location	Exposure assessment and pollutant measurements	Health outcome assessment	Major findings
Cancer						
*Floret N, Mauny F, Challier B, Arveux P, Cahn J-Y, Viel J-F. Dioxin emissions from a solid waste incinerator and risk of non-Hodgkin lymphoma. Epidemiol. 2003;14(4):392-8.[19]						
To address the issue of living in the vicinity of an incinerator and risk of NHL.	Case-control	One MSW incinerator with high dioxin emissions, operating since 1971 (most polluting combustion chamber was shut down in 1998).	222 cases of NHL and 10-1-match controls from Doubs, France.	Distance from incinerator – four dioxin exposure categories (by Gaussian dispersion model).	Incident NHL cases from the Doubs cancer registry (1980-1995).	Risk of developing NHL was higher (OR=2.3, 95% CI 1.4-3.8) among individuals living in the area with the highest dioxin concentration compared to those living in the area with the lowest dioxin concentration. Adjustment for SES characteristics did not alter the results.
*Viel JF, Arveux P, Baverel J, Cahn JY. Soft-tissue sarcoma and non-Hodgkin's lymphoma clusters around a municipal solid waste incinerator with high dioxin emission levels. Am J Epidemiol. 2000;152(1):13-9.[21]						
To examine the distribution of cancer cases that, if located mainly near the incinerator [of Besançon], could have been caused in part by dioxin.	Ecological	One MSW incinerator with high dioxin emissions, operating since 1971.	485 000 inhabitants in the département of Doubs (France) ; 110 cases of STS and 803 cases of NHL	Area around the incinerator. No pollutants measured .	Soft tissue sarcoma, non-Hodgkin's lymphoma and Hodgkin's disease (control group known to be unrelated to dioxin emissions) from Doubs cancer registry (1980-1995).	Significant disease clusters of STS (SIR=1.44, p=0.004) and NHL (SIR=1.27, p=0.00003) were found around the incinerator. No specific spatial distribution for Hodgkin's disease. Confounding by SES, urbanization or patterns of medical referral are unlikely.
Viel J-F, Daniau C, Goria S, Fabre P, De Crouy-Chanel P, Sauleau E-A, Empereur-Bissonnet P. Risk for non Hodgkin's lymphoma in the vicinity of French municipal solid waste incinerators. Env Health. 2008;7:51.[18]						
To examine the association [of increased risk for non-Hodgkin's lymphoma in the vicinity of some municipal solid waste incinerators] on a larger population scale.	Ecological	13 MSW incinerators, that operated for at least one year between 1972-1985.	4 administrative departments in France; 3974 NHL cases.	Distance from incinerator (5-20 km). Experts assessment of concentrations in exhaust gas, consensus reached with Delphi method. Gaussian atmospheric diffusion model computed "immission" estimates in the surroundings of MSWIs.	Incident NHL cases diagnosed 1990-1999, obtained from population based cancer registry.	Relationship at the block group level between risk for NHL and dioxin exposure, RR=1.120 (95% CI 1.002-1.251) for people living in highly exposed blocks compared to those living in slightly exposed block groups. Women's RR=1.178 (95% CI 1.013-1.369). Controlled for confounding factors: population density, urbanisation, socio-economic level, airborne traffic pollution, industrial pollution.

Objective	Method	Type of facility and dates of operation	Population size and location	Exposure assessment and pollutant measurements	Health outcome assessment	Major findings
Viel J-F, Clément M-C, Hägi M, Grandjean S, Challier B, Danzon A. Dioxin emissions from a municipal solid waste incinerator and risk of invasive breast cancer: a population-based case-control study with GIS-derived exposure. Int J Health Geogr. 2008;7:1-8.[34]						
To examine the association between dioxins emitted from a polluting MSWI and invasive breast cancer risk.	Case-control.	One municipal solid waste incinerator operating since 1971.	434 breast cancer cases and 2170 population controls in the northeast of the city of Besançon, France.	Individual exposure estimated through exposure zones based on predicted ground-level air concentrations of dioxins (Gaussian dispersion model).	Incident invasive breast carcinomas from the Doubs cancer registry (1996-2002).	No increased risk for women <60 years old for any dioxin exposure category. Women >60 years old and living in the highest exposed zone were less likely to develop invasive breast cancer (OR=0.31, 95% CI 0.08-0.89). No control for confounding.
Pregnancy Outcomes						
*Cordier S, Chevrier C, Robert-Gnansia E, Lorente C, Brula P, Hours M. Risk of congenital anomalies in the vicinity of municipal solid waste incinerators. Occup Environ Med. 2004;61(1):8-15.[17]						
To assess at a regional level the impact of metal and dioxin emissions on birth effect rates.	Ecological – comparison of exposed and non-exposed communities	70 MSW incinerators, operating for at least one year between 1988 - 1997.	194 communities with <50 000 inhabitants exposed to dioxins from MSW incinerators and a reference population of 2678 non-exposed communities in southeast France.	Experts assessments were used to construct a semi-quantitative estimate of the emissions of each incinerator. The Delphi method was used to achieve consensus. A Gaussian plume model was used to compute 'immissions' for each category of pollutants within 10 km of the plant. 3 levels of dioxin exposure were used.	Four categories of malformations: minor, chromosomal, monogenic and other. The 'other major anomalies' consists of 23 subgroups. Data from population-base birth defects registry (1988-1997)	The rate of congenital anomalies was not significantly higher in exposed compared with non-exposed communities. The RRs of specific major anomaly subgroups, including facial clefts (RR=1.30, 95% CI 1.06-1.59) and renal dysplasia (RR=1.55, 95% CI 1.10-2.20) were higher in exposed communities. Among exposed communities, a dose-response trend of risk with increasing exposure was observed for obstructive uropathies (p= 0.07). Adjustments for year of birth, maternal age, department of birth, population density, average family income, and when available, local road traffic.

Objective	Method	Type of facility and dates of operation	Population size and location	Exposure assessment and pollutant measurements	Health outcome assessment	Major findings
*Cordier S, Lehébel A, Amar E, Anzivino-Viricel L, Hours M, Monfort C, et al. Maternal residence near municipal waste incinerators and the risk of urinary tract birth defects. Occup Environ Med. 2010;67(7):493-9.[20]						
To test the association between the risk of urinary tract birth defects and residence in the vicinity of municipal solid waste incinerators.	Case-control	21 active waste incinerators operating in the study period (2001-2003)	304 infants with urinary tract birth defects and 226 population controls in the Rhone-Alps region in France.	Emissions of dioxins/furans and of three groups of metals were measured during the relevant time periods. Experts consensually defined the distribution of gaseous and particulate phases for each pollutant. Exposure was modelled with Gaussian modelling in a zone of 10 km around the incinerator. Exposed women were classified into exposed above or below median exposure. Case families and control families answered a questionnaire on individual risk factors.	Births, stillbirths and medical terminations of pregnancy diagnosed with a renal birth defect from the Birth Defects Registry (2001-2003)	Increased risk of birth defects linked to above-median exposure to emissions from active MSW incinerators as atmospheric dioxins (OR=2.84, 95% CI 1.32-6.09), dioxin deposits (OR=2.95, 95% CI 1.47-5.92) and metals (OR=2.30, 95% CI 0.93-5.68) compared to non-exposed mothers. No excess risk related to exposure to other dioxin sources or pas MSW incinerator activity. Risks decreased when only interviewed cases were taken into account because the non-interviewed cases were more likely to live in exposed residential environments (OR=2.95, 95% CI 1.04-4.87). Control for confounding by other industrial emissions of dioxins, population density and neighbourhood deprivation. Individual factors (consumption of local food, alcohol consumption) were controlled for when possible.
*Tango T, Fujita T, Tanihata T, Minowa M, Doi Y, Kato N, et al. Risk of adverse reproductive outcomes associated with proximity to municipal solid waste incinerators with high dioxin emission levels in Japan. J Epidemiol. 2004;14(3):83-93.[14]						
To examine the adverse reproductive health effects associated with maternal residential proximity to these	Ecological – comparison of observed and expected number of cases.	63 MSW incinerators, dates of operation not provided.	Area of 10 km around incinerators: 225 215 live births, 3387 fetal deaths, 835 infant deaths in Japan.	Distance from incinerator: Circes of 10 km around incinerators, with zones of 1 km. The incinerators were known to have high (>80 ng TEQ/m^3) dioxin emissions.	Female live births (male/female sex ratio at birth), low birth weight (<2500g), very low birth weight (<1500g), infant deaths (< 1 year of age), infant deaths due to congenital malformations, neonatal deaths, (<4 weeks of age), neonatal deaths due to	None of the adverse reproductive outcomes showed significant excess for all the zones within 2 km of the incinerators. A significant peak-decline in risk with distance was found for infant deaths (p=0.023) and infant deaths with all congenital malformations

Objective	Method	Type of facility and dates of operation	Population size and location	Exposure assessment and pollutant measurements	Health outcome assessment	Major findings
incinerators with high dioxin emissions.					congenital malformations, , early neonatal deaths (<1 week of age), early neonatal deaths due to congenital malformations, spontaneous fetal deaths (non-induced deaths before the complete expulsion or extraction from the mother after the 12th week of gestation) and spontananeous fetal deaths with congenital malformations.	(p= 0.047). Stratification to prevent confounding by maternal age, gestational age, birth weight, total previous deliveries, past experience of fetal deaths, and type of paternal occupation. Confounding by SES was reported to be unlikely.
Lin C-M, Li C-Y, Mao IF. Birth outcomes of infants born in areas with elevated ambient exposure to incinerator generated PCDD/Fs. Environ Int. 2006;32(5):624-9.[35]						
To determine if elevated ambient exposure to incinerator generated polychlorinated dibenzo-*p*- dioxins and dibenzofurans (PCDD/Fs) may affect birth outcomes of exposed infants.	Cross-sectional	One MSW incinerator, operating 1992-1999.	6697 live infants born in 1991 and 6282 live born infants in 1997 in Taipei (Taiwan).	Average emission concentration of PCDD/Fs in the exhaust gas was measured as 6.47 ng TEQ/m^3 in 1997. PCDD/Fs plume simulated with air pollution dispersion model to estimate average concentrations.	Birth outcomes (including low birth weight, preterm delivery and sex ratio), birth weight, gestational age from the Taiwan Birth Registry.	The incinerator-generated dioxin poses little effects on birth weight (OR= 0.91 (95% CI 0.61-1.73) for highest exposure in 1991 and OR=1.06 (95%CI 0.71-1.57) for the highest exposure in 1997), and female birth (OR=1.0 (95% CI 0.86-1.06) for highest exposure in 1991 and OR=0.90 (95% CI 0.78-1.05) for highest exposure in 1997), but might pose small effects on gestational age (OR=0.86 (95% CI 0.65-1.14) in 1991 but OR=1.22 (95% CI 0.97-1.52) in 1997), although non-significant. Covariates included gender, birth order, maternal age and maternal education level to control for potential confounding. Unlikely to have affected results.

Objective	Method	Type of facility and dates of operation	Population size and location	Exposure assessment and pollutant measurements	Health outcome assessment	Major findings
Vinceti M, Malagoli C, Fabbi S, Teggi S, Rodolfi R, Garavelli L, et al. Risk of congenital anomalies around a municipal solid waste incinerator: a GIS-based case-control study. Int J Health Geogr. 2009;8:1-9.[36]						
To examine the relation between exposure to the emissions from a municipal solid waste incinerator and risk of birth defects.	Case-control	One MSW incinerator, operating 1968-2002, equipped with dry scrubbing for acidic gas pollutants since 1992, activated carbon device for dioxins, furans and mercury adsorption since 1994.	228 births and induced abortions in the Reggio Emilia municipality (Italy) and a corresponding series of control births.	No pollutants measured. GIS was used to estimate exposure.	Congenital anomalies in the offspring or in aborted foetuses (1998-2006).	No associations found between prevalence of anomalies in offspring and residing in areas with medium and high exposure. No dose-response relationships for any of the major categories emerged. ORs for congenital anomalies did not decrease after shut-down of the plant. Adjustments were made for SES and maternal age.
Vinceti M, Malagoli C, Teggi S, Fabbi S, Goldoni C, De Girolamo G, et al. Adverse pregnancy outcomes in a population exposed to the emissions of a municipal waste incinerator. SciTotal Environ. 2008;407(1):116-21.[37]						
To assess the rates of adverse pregnancy outcomes in women living or working near a municipal waste incinerator.	Cohort	One MSW incinerator operating since 1984.	3796.64 person-years to follow-up, in Modena (Italy). Subcohorts of high-exposure residents and intermediate-exposure residents; subcohorts of high-exposure workers and intermediate-exposure workers.	Estimation of concentration levels for high-exposure areas and intermediate exposure-areas, through two models based on maximum incinerator allowed plant emissions.	Spontaneous abortions and birth defects from hospital discharges in the Emilia-Romagna region and files of the Emilia-Romagna region IMER Birth Defects Registry (2003-2006).	No excess risk of miscarriage and birth defects was found. Miscarriages: Residential cohort: RR=1.00 (95% CI 0.65-1.48), most exposed cohort: RR= 0.87 (95% CI 0.22-2.38), occupational cohort: RR= 1.04 (95% CI 0.38-2.30) Birth defects: Residential cohort: RR= 0.64 (95% CI 0.20-1.55), most exposed cohort: RR= 0.68 (95% CI 0.00-4.41), occupational cohort: RR= 2.26 (95% CI 0.57-6.14) No control for smoking, diet, occupation and reproductive history, but SES status was available but unlikely to affect the results.

Objective	Method	Type of facility and dates of operation	Population size and location	Exposure assessment and pollutant measurements	Health outcome assessment	Major findings
Respiratory Function and Disease						
*Miyake Y, Yura A, Misaki H, Ikeda Y, Usui T, Iki M, et al. Relationship between distance of schools from the nearest municipal waste incineration plant and child health in Japan. Eur J Epidemiol. 2005;20(12):1023-9.[15]						
To examine the relationship between the distance of schools from the nearest municipal waste incinerator plant and the prevalence of allergic disorders and general symptoms among Japanese children.	Ecological	37 municipal waste incinerators, years of operation not specified.	450 807 children aged 6-12 years in Osaka, Japan.	Distance of elementary schools from an incinerator, in 5 groups with bands of 1 km.	Wheeze, atopic dermatitis, allergic rhinitis, headache, stomach ache and fatigue from elementary school surveys (1997).	Schools within 1 km and 2 km had more children with wheeze (OR=1.08, 95% CI 1.01-1.15 and OR=1.05, 95% CI 1.01-1.10) Associations were also found with distance and stomach ache (OR=1.06 95% CI1.01-1.11) and fatigue (OR=1.12 95% CI 1.08-1.17). Adjustments were made for grade, SES and access to health care.
Psychosocial Impacts						
*Elliott SJ, Wakefield SEL, Taylor SM, Dunn JR, Walter S, Ostry A, et al. A comparative analysis of the psychosocial impacts of waste disposal facilities. J Environ Planning Manage. 2004;47(3):351-63.[38]						
To compare residents' reactions to the type of facility (landfill vs. incinerator) in their locality and to explore the impact context (Ontario vs. BC) in order to determine whether there were differences in reactions across provinces.	Ecological	Three incinerators (operating since 1986, 1987 and 1978) and three landfills (in use since 1989, 1979 and 1994).	6 communities in Ontario and British Columbia, Canada.	Distance within a prescribed area (app. 2-5 km) around each site.	Psychosocial impacts: concern about the facility, health concern about the facility, actions taken in response to facility concerns and expressed intention to move due to concerns about the facility.	The type of facility is the strongest predictor of residents' awareness, concern and action taken in response to concerns, with residents living near a landfill site having higher scores on these aspects. Authors note that the socio-economic contexts between the sites are different, but cannot control for them. The analysis also included individual characteristics, the social network and the wider community.

Appendix D: Summary of peer-reviewed primary studies of health effects of solid waste incinerators with multiple waste streams. (* asterisk denotes statistically significant finding of health effect)

Objective	Method	Type of facility and dates of operation	Population size and location	Exposure assessment and pollutant measurements	Health outcome assessment	Major findings
Cancer						
*Biggeri A, Barbone F, Lagazio C, Bovenzi M, Stanta G. Air pollution and lung cancer in Trieste, Italy: spatial analysis of risk as a function of distance from sources. Environ Health Perspect. 1996;104:750–4.[39]						
To investigate the relationship between environmental pollution (including an incinerator) and lung cancer risk.	Case-control.	Incinerator (type and years of operation not further specified).	755 male lung cancer deaths (cases) and 755 male controls in Trieste (Italy).	Distance from incinerator (and other sources). Length of residence was not individually assessed. No pollutants measured.	Lung cancer as cause of death (case group) and deaths from other causes (control group) from the Cancer registry and Department of Pathology of the province of Trieste (1979-1981 or 1985-1986).	Risk of lung cancer was related with incinerator: excess OR of 6.7 (CI not reported) and a rapid decay moving away from the incinerator. Effects significant when adjusting for individual risk factors and spatial effects of the city center.
*Elliott P, Shaddick G, Kleinschmidt I, Jolley D, Walls P, Beresford J, et al. Cancer incidence near municipal solid waste incinerators in Great Britain. Br J Cancer. 1996;73:702-10.[40]						
To determine incidence of certain cancers in association with MSWI in the United Kingdom.	Cross-sectional. Comparison of observed to expected ratios of incident cancers using likelihood ratios for each of 7 bands with increasing distance from incinerator.	72 incinerators of household, industrial and hazardous waste, operating prior to 1976.	Population within 7.5 km of MSW incinerators in Great Britain; 177 252 cancer cases.	Distance from incinerator – in bands from 0 to 7.5 km. No pollutants measured.	Incidence data from national cancer registry (1974-1987). Cancers included: all cancers, stomach, colorectal, liver, nasal and nasopharyngeal, larynx, lung, connective, bladder, lymphatic and haematopoietic, Non-Hodgkin lymphoma, Hodgkin lymphoma, multiple myeloma, leukemia.	Association was found between proximity to incinerator and all cancers combined, stomach, colorectal, liver and lung cancer. However, all except liver were negligible after controlling for socioeconomic status. No association was found for other cancers.
*Knox E. Childhood cancers, birthplaces, incinerators and landfill sites. Int J Epidemiol. 2000;29(3):391-7.[41]						
To analyze childhood cancers around municipal waste incinerators and hospital incinerators.	Ecological. Compares distances from suspect sources to the birth address and to the death address of cancer-children who had moved house.	70 municipal waste incinerators, 307 medical waste incinerators.	Population of Great Britain; 22458 cancer deaths (children <16 years) in the U.K.	No pollutants measured. Address at death and at birth was recorded.	11 groups of cancers extracted from file (1953-1980): lymphatic, myeloid, monocytic and unclassified leukaemias, lymphomas, nephroblastomas, CNS-tumours, neuroblastoma, bone-cancers, other solid cancers and fatal benign tumours.	Significant excesses of migrations away from birthplaces close to municipal incinerators (highest ratio 2.01, no CI provided). Hospital incinerators gave analogous results. Ratios greatly exceed findings around non-combustion urban sites. No control for confounding.

Objective	Method	Type of facility and dates of operation	Population size and location	Exposure assessment and pollutant measurements	Health outcome assessment	Major findings
*Zambon P, Ricci P, Bovo E, Casula A, Gattolin M, Fiore AR, et al. Sarcoma risk and dioxin emissions from incinerators and industrial plants: a population-based case-control study (Italy). Environ Health. 2007;6:19-0.[42]						
To evaluate sarcoma risk in relation to the environmental pollution caused by dioxin emitted by waste incinerators.	Case-control	33 plants: 4 industrial waste incinerators, 10 MSW incinerators, 12 medical waste incinerators, 3 thermal power plants, 1 oil refinery and 3 industrial plants, some of them operating since 1960.	172 cases and 405 controls in the Province of Venice (Italy).	Emission levels calculated through historical reconstruction of the technology used by each plant. Residential history since 1960.	Incident cases of malignant sarcoma from the Veneto Tumour Registry (1990-1996).	Risk of developing sarcoma is higher (OR=3.3, 95% CI 1.24-8.76) among subjects with the longest exposure period and the highest exposure level. Excess risk observed for women (OR=2.41, 95% CI 1.04-5.59) and for cancers of the connective and other soft tissue (OR=3.27, 95% CI 1.35-7.93). No control for confounding, although nutrition and occupational exposure are reported to be unlikely.
Pregnancy Outcomes						
*Brender, JD, Zhan FB, Suarez L, Langlois PH, Moody K. Maternal residential proximity to waste sites and industrial facilities and oral clefts in offspring. J Occup Environ Med. 2006;48:565-572.[43]						
To examine the association between oral clefts and maternal residential proximity to waste sites or industries	Case-control	Contaminated sites and hazardous waste sites and industrial facilities including incinerators	1781 cases born with oral clefts and 4368 controls, Texas, USA	Sites were classified by whether heavy metals or solvents were present or released. 'Exposure' was defined as women living within one mile of a facility at the time of birth.	Cleft palate alone, cleft palate and cleft lip	Compared with women who lived farther, women who lived within a mile of any of these sites or facilities were not more likely to have offspring with oral clefts. Among women ≥ 35 years, oral clefts in offspring were associated with living within a mile of industrial facilities (odds ration (OR) = 2.4, 95% confidence interval (CI) = 1.3-4.2).

Objective	Method	Type of facility and dates of operation	Population size and location	Exposure assessment and pollutant measurements	Health outcome assessment	Major findings
*Cresswell PA, Scott JES, Pattenden S, Vrijheid M. Risk of congenital anomalies near the Byker waste combustion plant. J Public Health Med. 2003;25(3):237-42.[44]						
To determine whether the risk of congenital anomalies in a population resident close to a waste combustion plant located at Byker in the city of Newcastle upon Tyne, United Kingdom, was higher than in a population resident further away.	Ecological – spatial scan	One combustion plant, operating since 1988.	Residents living near an incinerator in Newcastle upon Tyne, United Kingdom; 81 255 live births	Distance from incinerator: comparison of residents living within 3 km of the plant compared to those living 3-7 km from it. Emissions data are available from 1994. Permitted limits were not exceeded.	Live birth data from the Office for National Statistics. Cases of congenital anomalies (all live births, stillbirths, induced abortions and fetal deaths after 14 weeks gestation) from Northern Region Congenital Abnormality Survey (1985-1999). Chromosomal and non-chromosomal anomalies were analysed separately.	The overall risk of congenital anomalies in the inner zone was higher than that in the outer zone after opening of the site, although not statistically significant. Rate ratio=1.11 (95% CI 0.96-1.28). No difference between pre- and post-1988 rate ratios. In the final years of the study, rate ratios for chromosomal and non-chromosomal anomalies were higher in the inner zone (rate ratio=3.23, 95% CI 1.31-7.95) for chromosomal in 1998, rate ratio= 1.91 (95% CI 1.19-3.08) for non-chromosomal in 1995 and rate ratio= 1.99 (95% CI 1.06-3.74) for non-chromosomal in 1999, but not controlled for deprivation.
*Dummer TJB, Dickinson HO, Parker L. Adverse pregnancy outcomes around incinerators and crematoriums in Cumbria, north west England, 1956-93. J Epidemiol Community Health. 2003;57(6):456-61.[45]						
To investigate the risk of stillbirth, neonatal death and lethal congenital anomaly among babies of mothers living close to incinerators and crematoriums.	Retrospective cohort	4 incinerators operating between 1977 - 1993 (waste streams include biologicals and hazardous waste), 3 crematoriums operating between 1956 - 1993.	244 758 births to mothers living in Cumbria (England).	No emissions data available. Exposure computed using distance function (in km from the site). Multivariate logistic regression used to model how the risk varied in relation to proximity to incinerators and crematoriums, adjusting for known demographic risk factors.	Stillbirths (fetal death after 28 weeks of gestation), neonatal death (death within the first 4 weeks of life), lethal congenital anomaly (all neural tube defects, congenital heart defects, other congenital anomalies) from the Cumbrian Births Database and the Office for National Statistics (1956-1993). Causes of death confirmed by neonatologist.	Risk of stillbirth not significantly increased closer to incinerators. Risk of congenital anomaly was significantly higher (p<0.01), mainly for heart defects (OR= 1.12, 95% CI 1.03-1.22) and spina bifida (OR=1.17, 95% CI 1.07-1.28). Adjustments were made for social class, year of birth, birth order and multiple births.

Objective	Method	Type of facility and dates of operation	Population size and location	Exposure assessment and pollutant measurements	Health outcome assessment	Major findings
Respiratory Function and Disease						
*Mohan AK, Degnan D, Feigley CE, Shy CM, Hornung CA, Mustafa T, et al. Comparison of respiratory symptoms among community residents near waste disposal incinerators. Int Environ Health Res. 2000;10(1):63-75.[46]						
To expand the analysis of respiratory effects and living near an incinerator of previous studies.	Ecological	A biomedical incinerator, a municipal incinerator, a liquid hazardous waste-burning industrial furnace.	3 communities in North Carolina and 1 in South Carolina and 4 comparison communities.	Distance from incinerator.	Self-reported long duration respiratory symptoms (wheeze; morning cough and plegm or wheeze; awaken at night) and short duration (eye irritation, sore throat, cough, runny nose, nasal irritation), 1992-1994.	Higher prevalence of all self-reported respiratory symptoms in one community near a hazardous waste incinerator compared with its control community. Only respiratory symptoms of long duration remained significant after controlling for perceived air quality ($p<0.05$). Confounders controlled for: ethnicity, gender, marital status and educational status.
Hazucha MJ, Rhodes V, Boehlecke BA, Southwick K, Degnan D, Shy CM. Characterization of spirometric function in residents of three comparison communities and of three communities located near waste incinerators in North Carolina. Arch Environ Health. 2002;57(2):103.[47]						
To determine the extent to which stack emissions affect pulmonary function of healthy vs. self-identified subgroupd of “sensitive” (asthmatic, allergic) individuals.	Ecological	A biomedical incinerator, a municipal incinerator, a liquid hazardous waste-burning industrial furnace. Biomedical incinerator shut down in 1993.	3 communities with one incinerator (biomedical, municipal or liquid hazardous waste) and comparison communities upwind of the incinerator. 80 subjects per community (40 sensitives and 40 normals).	Air monitoring in community for a period of 35 days during three years (1992-1994).	Annual questionnaire and spirometry: forced vital capacity (FVC), forced expiratory volume in 1 sec. ($FEV_{1.0}$), forced expiratory flow rate over the middle 50% of the forced vital capacity (FEF_{25-75}).	Little difference between the incinerator and comparison communities in daily $PM_{2.5}$ concentrations, and contribution of incinerators was small. No differences in FVC, $FEV_{1.0}$, and FEF_{25-75} between the incinerator and comparison communities. No information on control for confounding.

Objective	Method	Type of facility and dates of operation	Population size and location	Exposure assessment and pollutant measurements	Health outcome assessment	Major findings
Hu S-W, Hazucha M, Shy CM. Waste incineration and pulmonary function: An epidemiological study of six communities. J Air Waste Manag Assoc. 2001 August;51(8):1185-94.[48]						
To examine the chronic effects of emission from waste incineration on the pulmonary function of residents of six communities.	Ecological	A biomedical incinerator, a municipal incinerator and a liquid hazardous waste-burning industrial furnace. Biomedical incinerator shut down in 1993.	3 incinerator communities and 3 comparison communities.	No pollutants measured. Exposure assessment: presence or absence of incinerator, distance to incinerator, incinerator exposure index.	Annual questionnaire and spirometric test s(1992-1994).	No statistically significant association between pulmonary function and the three incinerators, adjustment for gas oven/range use at home, length of residency and smoking history in the mixed linear models. Confounders examined: current respiratory symptoms, cigarette smoking, gas oven or range use at home, other indoor sources of air pollution, occupational exposure and educational level.
Lee JT, Shy CM. Respiratory function as measured by peak expiratory flow rate and PM10: six communities study. J Expo Anal Environ Epidemiol. 1999;9(4):293-9.[49]						
To determine whether the lung function of people in an incinerator community differs from a comparison community. (plus general air pollution-health effects research questions)	Ecological	A biomedical incinerator, a municipal incinerator and a liquid hazardous waste-burning industrial furnace. Years of operation not specified.	3 incinerator communities and 3 comparison communities.	Air monitoring station in each community (1992-1993). Exposed communities: < 2 miles from incinerator. Non-exposed communities: >2 miles from incinerator.	Respiratory symptoms compatible with chronic obstructive lung disease or with respiratory hypersensitivity from telephone interview. Lung function measured by spirometry.	PM10 concentrations were not related to variations of respiratory health. No differences in respiratory health between symptoms of COPD or hypersensitivity or lung function for those from an incin erator community and those of its comparison community. Cofactors in analysis: sex, age, respiratory hypersensitivity, hours spent outdoors, and surrogate measures for indoor air pollution exposure.

Objective	Method	Type of facility and dates of operation	Population size and location	Exposure assessment and pollutant measurements	Health outcome assessment	Major findings
Shy CM, Degnan D, Fox DL, Mukerjee S, Hazucha MJ, Boehlecke BA, et al. Do waste incinerators induce adverse respiratory effects? An air quality and epidemiological study of six communities. Environ Health Perspect. 1995 July-August;103(7-8).[50]						
To simultaneously measure air quality and respiratory function and symptoms in populations living in the neighbourhood of waste incinerators and to estimate the contribution of incinerator emissions to the particular air mass index in these neighbourhood.	Ecological	A biomedical incinerator, a municipal incinerator and a liquid hazardous waste-burning industrial furnace. Years of operation not specified.	3 communities with one incinerator (biomedical, municipal or liquid hazardous waste) and comparison communities upwind of the incinerator. 80 subjects per community (40 sensitives and 40 normals).	Pollutants measured: air monitoring station in each community (PM2.5 and PM10) and quantitative emissions data from incinerators. Data put in model to estimate the impact of the incinerator at each monitoring site. Exposure assessment by assigning study subject to incinerator or comparison community, assigning average 12h ambient air pollution concentration, estimating individual exposures.	Respiratory symptoms (wheezing and other asthma-like symptoms, by questionnaire) Spirometral lung function tests, nasal lavage samples. Yearly, 1992-1994.	No differences of concentrations of PM among communities. Incinerator emissions did not have an impact on routinely monitored air pollutants. No community differences in the prevalence of chronic and acute respiratory symptoms and no differences in baseline lung function tests or in the average peak expiratory flow rate measured over a 35-day period. Potential confounders in logistic regression analysis: sex, age, race, education, current smoking status, exposure to environmental tobacco smoke in the home, occupational exposure to chemicals, use of an unvented gas or kerosene heater, cooking with gas or kerosene, use of central air conditioning and mould problems in the home.

Objective	Method	Type of facility and dates of operation	Population size and location	Exposure assessment and pollutant measurements	Health outcome assessment	Major findings
Psychosocial Impacts						
*Lima ML. On the influence of risk perception on mental health: living near an incinerator. J Environ Psychol. 2004;24(1):71.[51]						
To analyze the relation between risk perception and psychological symptoms.	Ecological – surveys among residents before and after the incinerator started working.	One waste incinerator, operating since app. 1998.	906 residents around the incinerator in Oporto, Portugal.	40% lives within 1.24 miles of the site, 29 % at 3 miles and the rest at 6 miles. Interviews were conducted. Risk perception was assessed by 5 items: general evaluation of risk, the perceived likelihood of the incinerator provoking a series of negative consequences (headaches, respiratory diseases, air pollution and auditory pollution).	Psychological symptoms: stress; anxiety and depression. Perceived environmental quality and attitudes towards the incinerator were also assessed.	Risk perception is more acute for residents living close to the site, who also have a less favourable attitude; there is an habituation effect for those living closer to the incinerator: they now have less extreme attitudes and a lower estimation of risk; psychological symptoms are associated with socio-economic variables, but also with environmental annoyance; for those living close to the site, risk perception and the interaction between risk perception and environmental annoyance significantly increase the prediction of psychological symptoms.

Appendix E: Health assessment methods

There are two basic approaches to assessment of health impacts: human health risk assessment (HHRA) and sociologic methods (ranking and qualitative). HHRA is a quantitative method that arises from an epidemiologic and toxicological approach to human health impacts and models health outcomes attributable to specific environmental emissions. Sociologic methods use ranking and/or qualitative descriptions to compare health outcomes. These methods are described in more detail below.

HHRA is quantitative approach that uses associations between specific environmental parameters and health outcomes that have been established through epidemiologic and/or toxicologic research to predict health outcomes caused by the environmental outputs of a project/policy. These predictions inform a risk management strategy that outlines project/policy options and associated health risks. HHRA is standard method with several steps (Figure 1). First the issue is identified and defined, the hazards are characterised including dose-response assessment and the exposures are assessed including pathways, populations and predicted intakes. These hazard and exposure assessments inform risk characterisation: the likelihood of adverse health effects is modeled and uncertainty evaluated. During the final step, risk management, the assessed risk is placed into social, economic, environmental and political context and recommendations are made. HHRA methodology is strong at predicting health outcomes for projects or policies when the health effects of substances of concern are well established (i.e. dose-response relationships, effect estimates) and exposure can be accurately estimated (e.g mortality attributable to incremental increases in ambient fine particulate matter). HHRA is limited to substances/emissions that are measured and for which toxicity and dose-response relationships are known. Furthermore HHRA is generally limited to disease outcomes. Other non-disease determinants of health, such as equity and employment with are generally excluded from the assessment.

In contrast, the sociologic approaches are ideologically aligned with community-based health promotion models and the Ottawa Charter on Health Promotion.[78,79] The assessment itself consists of prediction of the direction and magnitude of potential health impacts. HAs true to this method emphasize participation as a key objective of the assessment, with stakeholders driving the process and performing much or all of the assessment. The objectives are not only the prediction of potential health impacts and their direction (negative/positive) but also community empowerment in decision-making. A broad range of health effects may be estimated including illness/disease as well as employment, social factors and other determinants of health; however in practice a smaller number of key health effects are selected for assessment. Recommendations often include actions to mitigate potential impacts. Published HAs are heterogeneous in terms of: which evidence to include, who is doing the assessment, the level of community/stakeholder participation, and whether equity will be considered. Most of these HAs follow some variation of the standard HIA process.

Risk assessment model (adapted from enHealth Council[9], p.5).

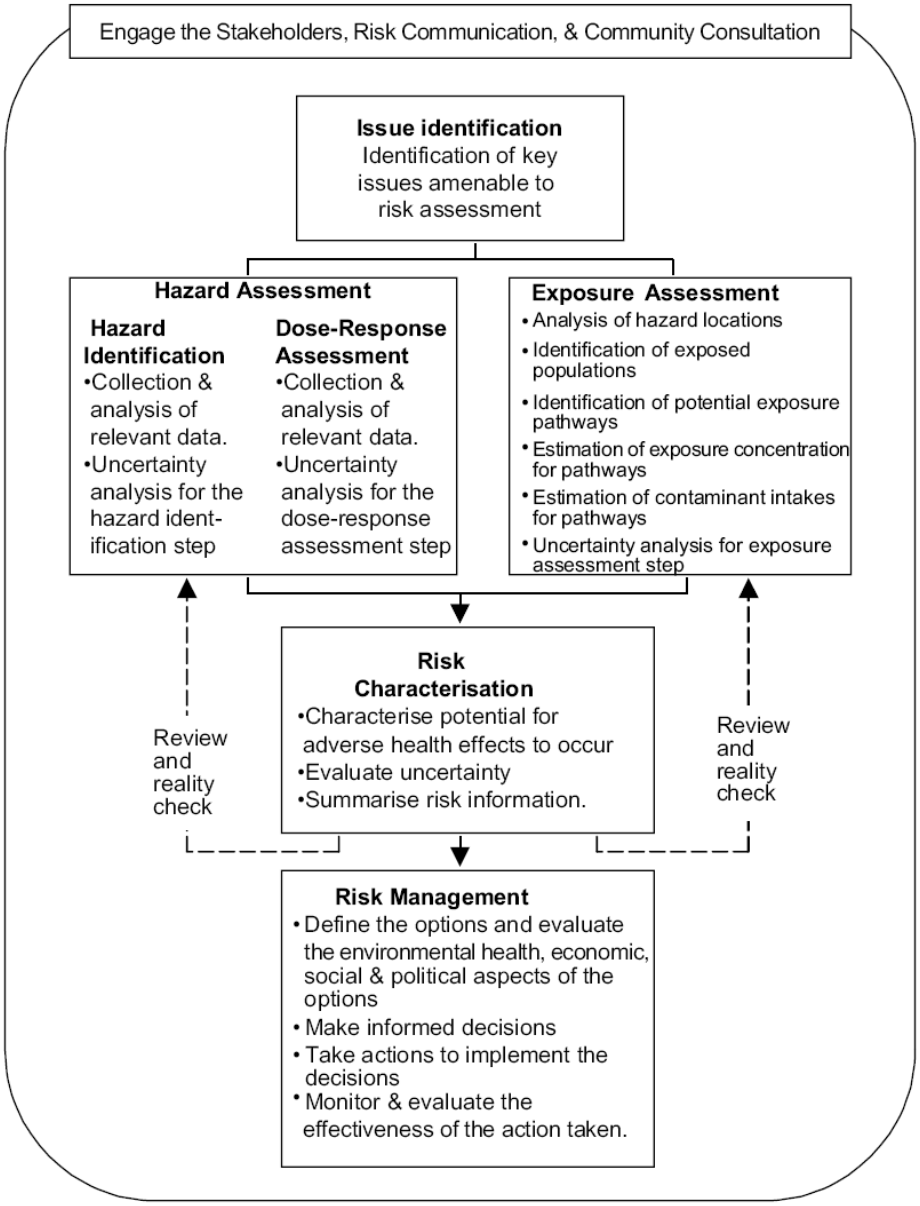


Figure E.1 *Human health risk assessment model*[80-p5]

Appendix F: Kamloops Microgasificiation Plant Proposal Case Study

Introduction

In 2006, the Aboriginal Cogeneration Corporation (ACC), a Canadian-based company, initiated a partnership with the Energy & Environmental Research Center at the University of North Dakota to develop a technology that would convert railway ties to energy. Termed 'microgasification', this process uses heat, pressure, and steam to convert solid materials into a synthetic gas (syngas).[81] The gas can then be used as energy for a variety of processes. ACC had proposed selling this energy from their proposed Kamloops plant to BC Hydro, a provincial Crown Corporation. Heat produced would also be potentially for sale.

In August 2008, ACC proposed a plan to build a microgasification plant in Kamloops, British Columbia (BC), Canada to convert creosote-treated railway ties to energy.

This case study will examine the permitting and review processes that went into examining the potential health and environmental impacts such a plant would have had on the residents of Kamloops. This is NOT an attempt to conduct an environmental or health impact assessment on this proposal.

Summary of Events

In August 2008, the ACC proposed a plan to build a microgasification plant in Kamloops, British Columbia (BC), Canada to convert creosote-treated railway ties to energy. Kamloops is a mid-sized city of approximately 92 000 people in the interior of British Columbia.[82] Figures 8 and 9 show the proposed location of the plant in relation to populated residential areas in Kamloops. In August 2009, the ACC applied for an air discharge permit from the Ministry of Environment (MoE). Previously (April 2009), the MoE met with ACC representatives for a pre-application meeting; consultation requirements and scope of the environmental impact assessment were agreed upon at that meeting. Subsequently, the ACC conducted its consultation and fulfilled its legal requirements without MoE involvement. Under the *Public Notification Regulation* of the *Environmental Management Act*, the ACC was required to notify the public by placing an advertisement in the Kamloops Daily News and the BC Gazette. Upon advertising, the public had 30 days to provide comments; no comments were received during those 30 days. The public started to become aware of the issue following an August 22, 2009 news story in the Kamloops Daily News, detailing ACC's plans for a microgasification plant[3.] Following the news story, the MoE extended the 30-day public consultation period; this period ran from June 15, 2009 to January 7, 2010. Over 100 residents expressed their concerns directly to the MoE. These concerns were summarized in a letter the MoE sent to the ACC in September 2009 requesting additional information in support of their air discharge permit application. This was provided by the ACC to the MoE in October 2009.

On August 30, 2009, a citizens group (*Save Kamloops*) organized in opposition to the ACC's building of a microgasification plant in Kamloops and brought in Paul Connett PhD, a professor of chemistry at a New York state liberal arts college, to speak at a public meeting. The next day he addressed Kamloops city councillors about the plant. Following the presentation on September 1, 2010, city councillors voted unanimously to oppose the microgasification plant. Dr. Connett's presentation highlighted: the inexperience of the operator, the scaling up of the North Dakota research project from a small scale operation to a commercial operation, the fact that commercial gasification plants have had a poor track record in that their actual environmental record is worse than modeling, the potential health effects of burning creosote-treated railway ties, and the disposal of toxic by-products. The presentation also convinced those in attendance that the microgasification plant was an "incinerator in disguise."

Following a comprehensive and rigorous review of the proposal by professional ministry staff, who are also residents of Kamloops, a permit was granted by the Ministry of Environment (MOE) January 7, 2010. However, within 30 days a private citizen appealed the decision. A public forum of over 500 residents, hosted by the Kamloops Chamber of Commerce, was held in March 2010 to solicit public opinion.

Reaction was unanimous at the public forum. Residents were concerned with the untested microgasifier plant and any adverse health effects that may follow.

Shortly thereafter, the ACC's CEO stated that the plant would not be built in Kamloops. However, the permit remains valid. An appeal to the environmental appeal board, initially scheduled for December 2010, has been postponed indefinitely due to the fact that the ACC no longer has plans to build a plant in Kamloops.

Figures 8 and 2 depict the proposed location of the microgasification plant in relation to the rest of Kamloops. It is important to note the proximity of the Kamloops Indian Reservation to the proposed site. Although the name of the ACC involves the term "Aboriginal", it was not on Aboriginal land. However, the ACC could have easily moved across to the Indian Reservation and not needed a MoE permit or Interior Health Authority approval.

Table F.1 *Summary of Events*

Date	Event
August 2008	ACC announces intention to build microgasification plant in Kamloops
April 23 2009	Pre-application meeting between MoE and ACC on consultative process
June 15, 2009 – January 7, 2010	Public consultation
August 24, 2009	ACC applies for an air discharge permit from MoE
August 30, 2009	Presentation by Paul Connett, PhD to the public at Thompson Rivers
September 1, 2010	Kamloops City Council votes unanimously to oppose the building of a microgasification plant in Kamloops after presentation by Dr. Connett and several members of the public.
January 7, 2010	Air discharge permits granted by MoE; subsequently appealed.
March 12, 2010	Public forum, hosted by Kamloops Chamber of Commerce
March 18, 2010	CEO of ACC announces that microgasification plant will not be built in Kamloops
September 16, 2010	Appeal against ACC permit adjourned indefinitely

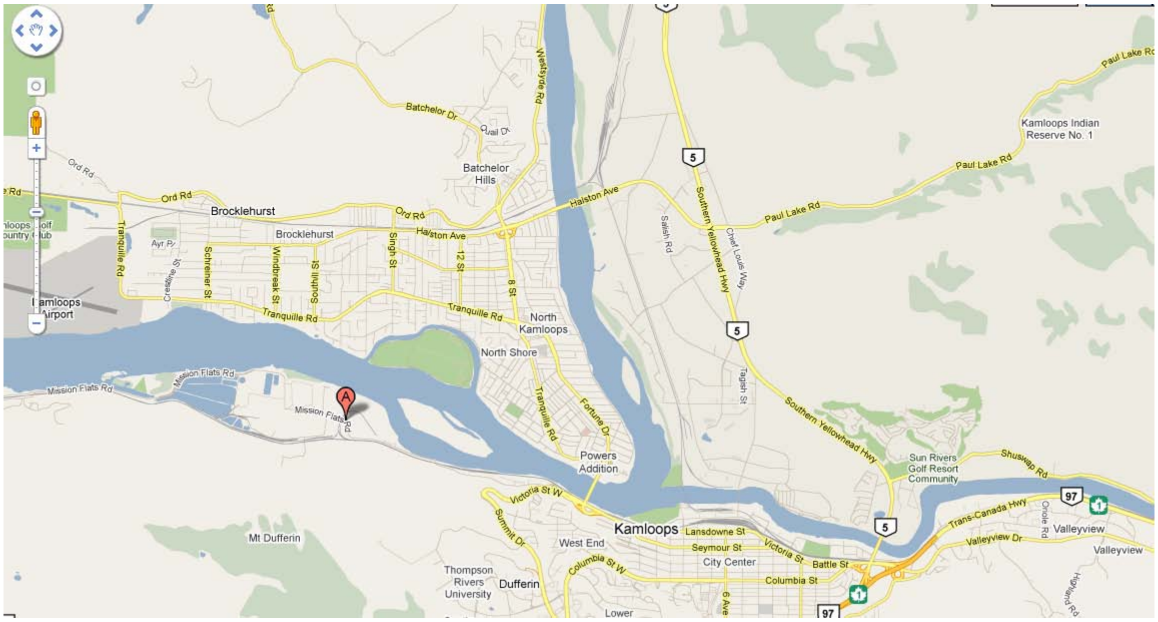


Figure F.1 *Proposed site of ACC microgasification plant in relation to Kamloops. Note the proximity of the Kamloops Indian Reservation. © 2010 Google Maps*

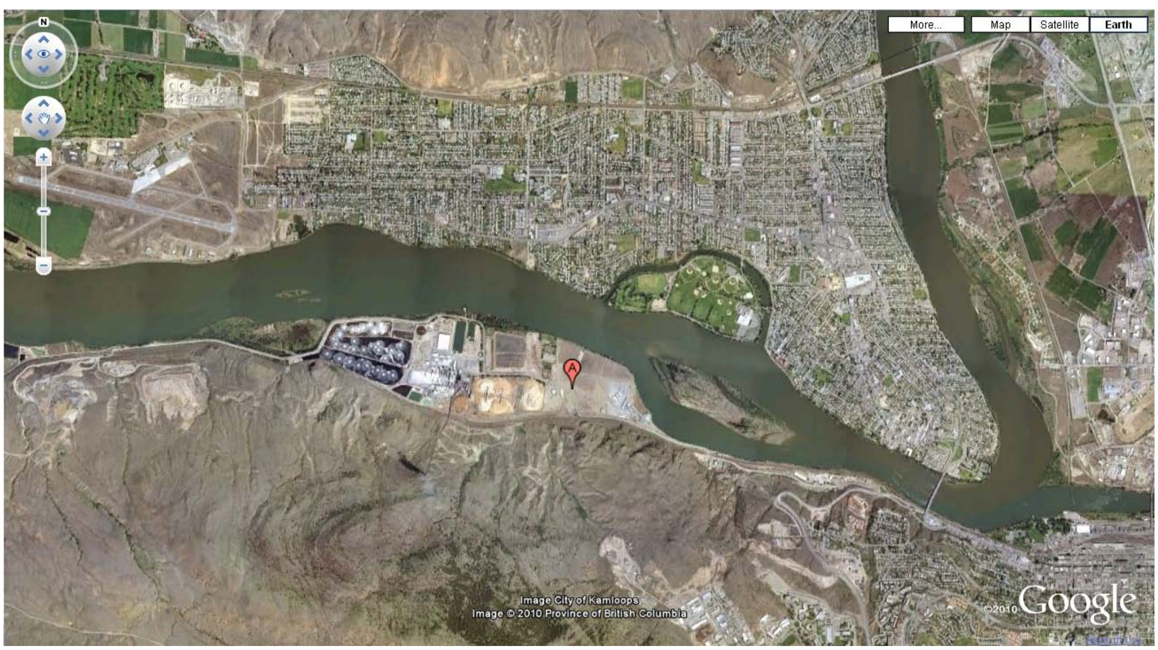


Figure F.2 *Proposed site of ACC microgasification plant in relation to Kamloops. © 2010 Google Earth*

Technology, Inputs, and Outputs

The ACC microgasification uses a downdraft, fixed bed system (see Figure 10).[83] This technology reduces the tar content of the syngas, leading to lower emissions, when compared with other gasifiers. Their main reactor is 1 megawatt (MW) based on a combustion of about 1.5 to 2 tons of biomass per hour or 15 000 tons per year. The ACC claims that although the Kamloops site was proposed to process railway ties, their technology enables any type of biomass to be utilized.

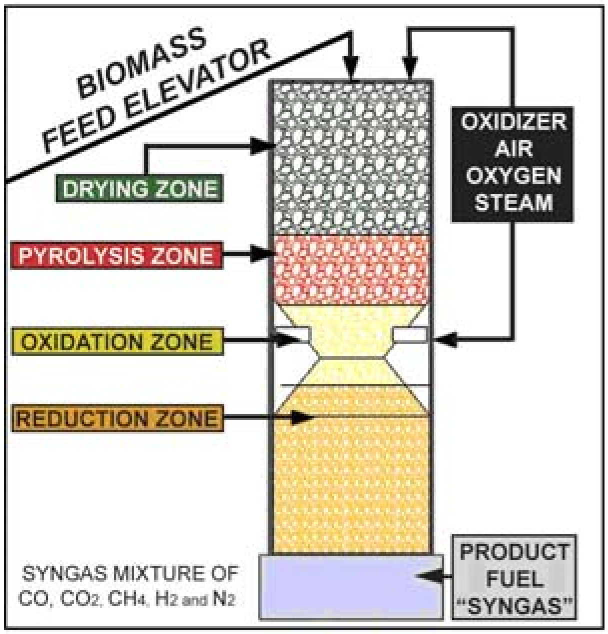


Figure F.3 *Downdraft microgasification process*

Assessment of Health Impacts

Kamloops is a mid-sized city of approximately 92 000 people in the interior of British Columbia.[82] Figures 8 and 9 show the proposed location of the plant in relation to populated residential areas in Kamloops. The west end of Kamloops is directly downwind of the proposed plant, and would therefore be most affected by air emissions.

Health effects were not assessed by the ACC and the BC MoE as part of their waste discharge permitting process for a Biomass to Energy facility. However, the ACC did conduct internal reviews on which this case study will focus. The Interior Health Authority was also consulted on the entire project; their main concern was with potential health impacts associated with air emissions from the plant. In a December 7, 2009 letter, the following recommendations were outlined for the ACC:

- best available technology be used to achieve the lowest possible emission levels;
- a sufficient sampling regime be in place;
- contingency plans be incorporated into the permit;
- operation of the flare stack should function on restrictive operating conditions only;
- noted program to screen railway ties to limit potential contaminants being introduced to the process should be clearly defined and administered;
- operation is conditional on the use of CP (Canadian Pacific) railway ties only;
- a dust control monitoring program should be in place;

- fire prevention and control measures are maintained to the satisfaction of the Kamloops Fire Department.

In BC, an environmental impact assessment (EIA) is triggered when the proposed project will generate more than 50 MW of energy or if more than 225 tonnes per day of municipal waste is incinerated.[84] Thus, an EIA was never done as the threshold to trigger an EIA was not reached.

The following evaluation of the assessment process undertaken by the ACC and the MoE is based on the Health Impact Assessment framework for municipal solid waste management developed by Toronto Public Health. [85]

Environmental Factors

Air Quality**:** An air quality assessment was done by Stantec consultants for the ACC. This assessment was subsequently reviewed by staff at the MOE. The proposed site of the microgasification plant sits next to the Domtar pulp mill. The maximum rate of air emissions discharge from the pulp mill is 26 000 m^3/minute with a maximum concentration of particulate of 230 mg/m^3. The estimated maximum rate of air emissions discharge from the ACC plant is 300 m^3/minute with a maximum concentration of 5 mg/m particulate matter.[86] The ACC also conducted its own independent airshed modeling and research on emissions associated with gasification and creosote. Medical Health Officers and Environmental Health Officers at the Interior Health Authority and environmental health scientists at the BC Centre for Disease Control were consulted. The BC Lung Association also reviewed the permit. Assuming that the plant ran according to its specifications, none of these organizations had any concerns regarding the potential health impact of the plant. Health of the population, with respect to air quality, was adequately taken into account, based on the internal air quality assessment, airshed modeling, and research on emissions done internally by the ACC.

Modeling shows very low particulate matter emissions, as low as a single wood-burning stove.

Odour: Assessed by both the MOE and internally by the ACC, they concluded that due to the small size of the plant, any odour would be negligible. Possible impacts on odour to health (e.g., quality of life) were addressed and noted to be negligible.

Surface Water Quality: The permit requires the ACC to “make all reasonable efforts to construct and maintain surface water diversion works to prevent surface water from entering or leaving active areas of the site.”

The following environmental factors were not explicitly addressed: groundwater quality, soil quality, land use, vegetation noise, and the built environment

Other Determinants of Health

The only determinant of health mentioned was the socio-economic benefit of the creation of up to 25 jobs. However, the health impacts of this were not assessed.

The following factors were not addressed:

- Access to services, such as health services, social services, education, transportation, and leisure activities;
- Lifestyle factors, such as diet, physical activity, smoking, alcohol use, drug use, and sexual behaviour;
- Equity factors, such as age, sex, minorities or other disadvantaged groups, and ability.

Overall Evaluation

After reviewing the above information, the MOE concluded that the environmental impact would be minimal. The major emission, particulate matter to the air, was found to be very low. The Ministry's risk rank value, based on a quantitative environmental risk assessment, was considered to be low-risk. Therefore, a waste discharge permit was granted January 2010.

Discussion and Future Directions

In this case study of the proposed microgasification plant in Kamloops, a limited environmental assessment was done. Because of the small size of this facility (1MW), a formal environmental impact assessment was not triggered. However, experts from the MoE staff, including an air quality meteorologist, a chemist, a chemical engineer, and an environmental protection officer, have reviewed technical information and evidence to support the application. MoE staff also conducted its own independent airshed modeling and research on emissions associated with gasification and creosote. A formal review was provided only by the company involved.

Despite the conclusion of low health risk based on environmental assessment, other key social determinants of health were not addressed in the process: lifestyle (such as diet, physical activity, smoking, alcohol use, drug use, and sexual behaviour), equity, and socio-economic issues; for example, perception by the adjacent residents that the plant would decrease the land value and thereby affect their socioeconomic status, and ultimately their health. While the ACC did address the economic benefits of potentially providing up to 25 jobs for the community, they did not address the potential negative socio-economic effects of the plant.

At a public forum held in March 2010 to elicit public reaction, local residents opposed the plant. Participants were concerned with the fact that a plant of this type had never been used to convert creosote-treated railway ties to energy. They were concerned with the environmental and human health effects from emissions of such a plant. Moreover, Terry Lake, a Kamloops-North Thompson Member of the Legislative Assembly (MLA), suggested that "…public consultation is important and, in this case, it should have been done ahead of time to avoid the problems that arose."[87]

A systematic Health Impact Assessment (HIA), taking into consideration determinants of health, may have alleviated some public concerns. It has been proposed internationally that Health Impact Assessments (HIAs) be conducted as part of an EIA.[88] In future, plans to implement the practice of HIAs should be done in the context of EIAs. A formal EIA was not done in this case. HIAs can be a method of involving the public in projects of local significance.

The perception of risk to public health must also be considered. A thorough and complete HIA and EIA will not alleviate fears of the public unless improvements in risk communication are made as well. Letters to the editor at the Kamloops Daily News echoed the frustration of the citizens of Kamloops—"Experimental gasifier immoral,"[89] "Are you willing to gamble with creosote?"[90] and "Everyone should say no to evil plan." were some of the titles of letters to the editors during the winter of 2010. These letters illustrate the disconnect between the *perception* of risk in the public and the scientific *facts* of the review process.

Conclusions

A limited environmental assessment was done on the proposed microgasification plant in Kamloops. Given the assessment that risks to health were minimal, a formal health impact assessment (HIA) was not conducted. It is possible that an HIA may have addressed and mitigated some of the concerns from the residents of Kamloops. However, earlier, more active, public consultation may have been particularly effective to allay concerns of the public, since their perception was greater than scientific evaluation of the risk. This consultation could have been part of the HIA or stand-alone.

Appendix G: Toronto Public Health - Health Impact Assessment Case Study

Background

The City of Toronto had a goal to divert 70% of its residential solid waste from landfill by the year 2010. In addition to existing waste diversion programs, it is believed that a new mixed waste processing facility is needed to process residual waste. A study was undertaken to define a preferred residual waste management strategy for the planning period 2010 to 2035. City Council could then use this information to make decisions regarding the development and implementation of a residual waste system or the development of one or more waste processing facilities.

Seven potential residual waste diversion technologies[x] were evaluated using screening criteria[y]. Two technologies met the criteria[z] and were then compared to landfill for all waste without a mixed waste processing facility (the status quo). This comparison involved the use of a Health Impact Screening Assessment in accordance with the Toronto Public Health (TPH) Health Impact Assessment (HIA) Framework (see Table 13). Further, an economic evaluation and Life Cycle Assessment of potential environmental benefits or impacts associated with each of the processing options were also conducted.

Table G.1 *TPH HIA Framework – determinants of health indicators*

Environmental Factors		
Air quality	Groundwater quality	Vegetation
Odour	Soil quality	Noise
Surface water quality	Land use	Built Environment
Non-Environmental Factors		
Social and economic factors		
Income / Poverty	Family cohesion	Housing
Employment	Community & social cohesion	Social exclusion
Education	Crime	

[x] 1. Mechanical Separation for Material Recovery; 2. Mechanical Biological Treatment (MBT) with Compost-Like Output (CLO) diverted; 3. MBT with the CLO produced going to landfill; 4. MBT with CLO diverted and Refuse Derived Fuel (RDF) production; 5. Mechanical Separation with RDF Production; 6. Thermal Treatment with Energy Production; and 7. Steam Classification Process

[y] Ability to divert 75,000 tonnes per year (tpy) from landfill; Ability to conform to Ministry of the Environment (MOE) Policy Statement; Realistic ability to market recovered materials; Ability for markets to meet Ontario environmental standards; Ability to dispose of the residual material in the Green Lane Landfill;

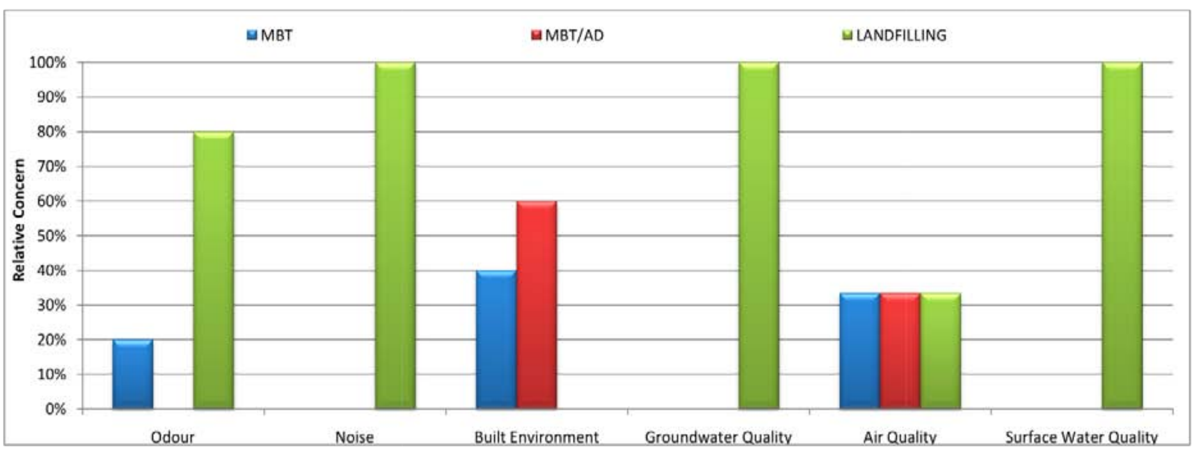
Technology to have a proven operating history; and Ability to have facility under construction by 2010.

[z] MBT, with the CLO produced being used for land reclamation or landfilled. MBT technology further divided into MBT with aerobic composting; and MBT with anaerobic digestion (AD).

Non-Environmental Factors		
Lifestyle factors		
Diet	Smoking	Drug use
Physical activity	Alchoho	Sexual behaviour
Access to services		
Health services	Social services	Leisure
Education	Transportation	
Equality		
Age	Minorities/disadvantaged group	
Sex	Ability	

HIA Applied

For this study, a Pre-Screening Health Determinants decision tool was developed. This tool prioritized the technology options based on their potential impacts on determinants of health, consistent with the determinants of health categories identified in the HIA tool for TPH. A MS Excel workbook with worksheets was the tool that allowed for selection and ranking of factors to be used to evaluate technology options and ranking of each technology with respect to the factors, resulting in identification of different options regarding the relative concern to human health (see Figure 11 and Figure 12).



• LANDFILL is of greatest relative concern • MBT of little relative concern • MBT/AD is of little relative concern	• LANDFILL is of greatest relative concern • MBT and MBT/AD are of little relative concern	• MBT/AD is of slightly more relative concern than MBT • LANDFILL is of least relative concern	• LANDFILL is of greatest relative concern • MBT and MBT/AD are of least relative concern	• All options are of equal relative concern • Emissions from waste transportation are assumed to be the same • Emissions from curing process for MBT and MBT/AD are assumed to be the same as LANDFILL	• LANDFILL is of greatest relative concern • MBT and MBT/AD are of least relative concern

Figure G.1 *Environmental option comprehension summary*

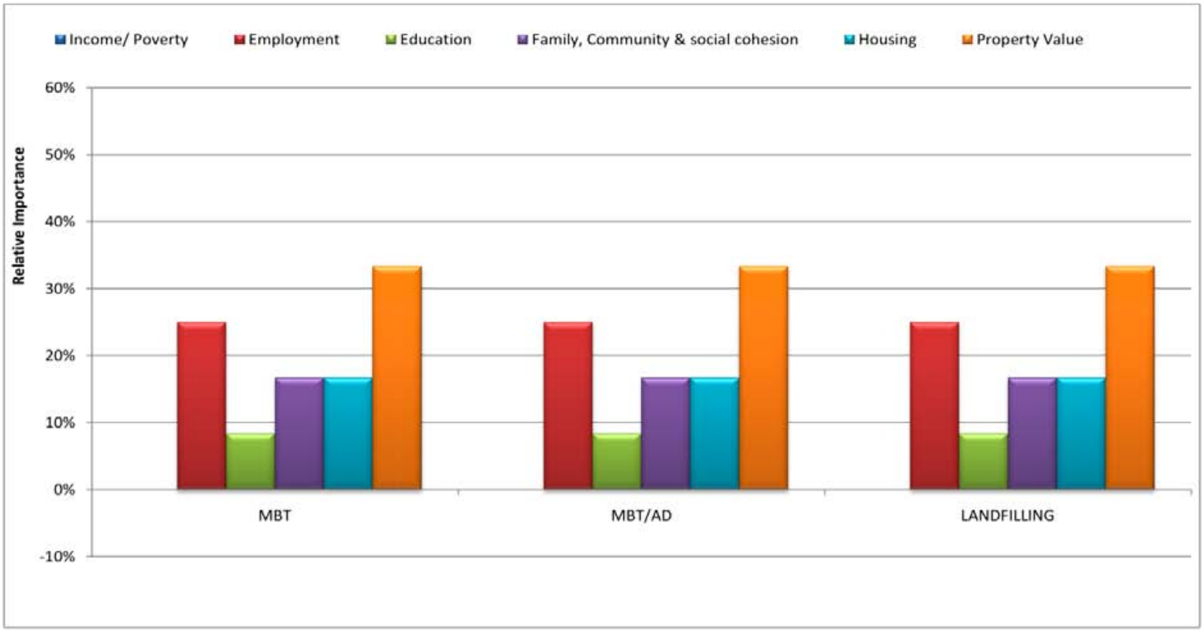


Figure G.2 *Social-economic decision factor summary*

Determinants of Health

The TPH HIA Framework identifies the following 5 categories of determinants of health:

- Environmental Factors (air quality, odour, surface water quality, groundwater quality, soil quality, land use, vegetation, noise, and built environment);
- Access to Services Factors (health services, education, social services, transportation, and leisure);
- Lifestyle Factors (diet, physical activity, smoking, alcohol, drug use, and sexual behaviour);
- Equality Factors (age, sex, minorities or disadvantaged group, and ability);
- Social-Economic Factors (income/poverty, employment, education, family cohesion, community & social cohesion, crime, housing, and social exclusion)

Table 14 provides an example of the evaluation of Environmental and Social-Economic Factors categories. From the 5 categories of health determinants, the screening tool identified Environmental Factors as having the greatest possible impact on human health for the mixed waste processing options under consideration (the decision tool identified odour, noise, built environment, groundwater quality, air quality, and surface water quality as the environmental factors with the greatest importance).

General TPH HIA Process

HIA aims to identify what potential changes in the *determinants of health* might result from a policy (or program or project) and what effects these changes might have on the health of a population. The HIA should also assess the distribution of potential health effects on different sub-populations to identify potential health inequities.2

The overall TPH HIA process is presented in Figure 13. Identification of the determinants of health that need to be evaluated to understand the potential health impacts of the proposed project/policy is specifically mentioned as being an important part of the Scoping Phase of the HIA.

Table G.2 *Example of Environmental and Social-Economic Factors Assessments; Potential Health Impacts and their Potential Source*

Environmental Factor	Potential Impacts					Potential Health Impacts	Potential Sources or Controls		
	Not Enough Information	Positive	Neutral	Negative	N/A		MBT	MBT/AD	LANDFILL
Odour				☑		• Perceived health impact due to diminished air quality • Odours may prevent nearby residents from enjoying outdoor activities • Lack of exercise • Sedentary lifestyle	• Trucks transporting waste • Escaping from facility when doors are open • Curing compost outdoors (3 – 12 months) • Waste operations are primarily indoors and biofiltration system will capture odours	• Trucks transporting waste • Escaping facility when doors are open • Curing compost outdoors (3 – 12 months) • Waste operations are primarily indoors and biofiltration system will capture odours	• Trucks transporting waste • Open landfill cells • No system to capture/minimize odours
Noise				☑		• Lack of sleep • Increased stress from noise • Diminished quality of life	• Trucks transporting waste (daytime hours only) • Air handling system • Front-end loaders moving compost (daytime hours only)	• Trucks transporting waste (daytime hours only) • Air handling system • Front-end loaders moving compost (daytime hours only)	• Trucks transporting waste (daytime hours only) • Heavy equipment moving waste, covering completed cells, preparing new cells (daytime hours only)
Built Environment				☑		• Increased stress from constant sight of an unwanted building • Large structure that disrupts the natural environment	• Two storey building large enough to house MBT equipment	• Two storey building large enough to house MBT equipment • Storage tanks for anaerobic digestors	• Landfill – when complete large earth mounds
Groundwater Quality				☑		• Potential exposure to impacted potable water • Use of potentially impacted groundwater for crop irrigation and/or livestock watering	• Controls to collect water from facility	• Controls to collect water from facility	• Leachate collection and control at facility
Air Quality				☑		• Increased hospital admissions and/or respiratory complications (i.e., asthma) due to compromised airshed	• Release of gasses such as CH_4, CO_2 • Possible release of VOCs • Biofilter	• Release of gasses such as CH_4, CO_2 • Possible release of VOCs • Biofilter	• Release of gasses such as CH_4, CO_2 • Possible release of VOCs • Landfill gas collection system
Surface Water Quality				☑		• Impact to recreational surface water and exposure to contaminants	• Runoff from compost while curing	• Runoff from compost while curing	• Runoff from landfill
Soil Quality			☑			• Incidental ingestion of soil by nearby residents or trespassers • Uptake of contaminants in soil by livestock or agricultural crops	• Compost product not to be used in area	• Compost product not to be used in area	• Not applicable
Vegetation			☑			• Uptake of contaminants by agricultural crops • Ingestion of impacted produce	• Potential use of impacted groundwater for crop irrigation or livestock watering	• Potential use of impacted groundwater for crop irrigation or livestock watering	• Not applicable
Land Use			☑			• Decrease in property value leading to stress	• None – landfill already present	• None – landfill already present	• None – landfill already present
Radiation			☑			• Ingestion of radioactive material	• Disposal of medication in waste	• Disposal of medication in waste	• Disposal of medication in waste

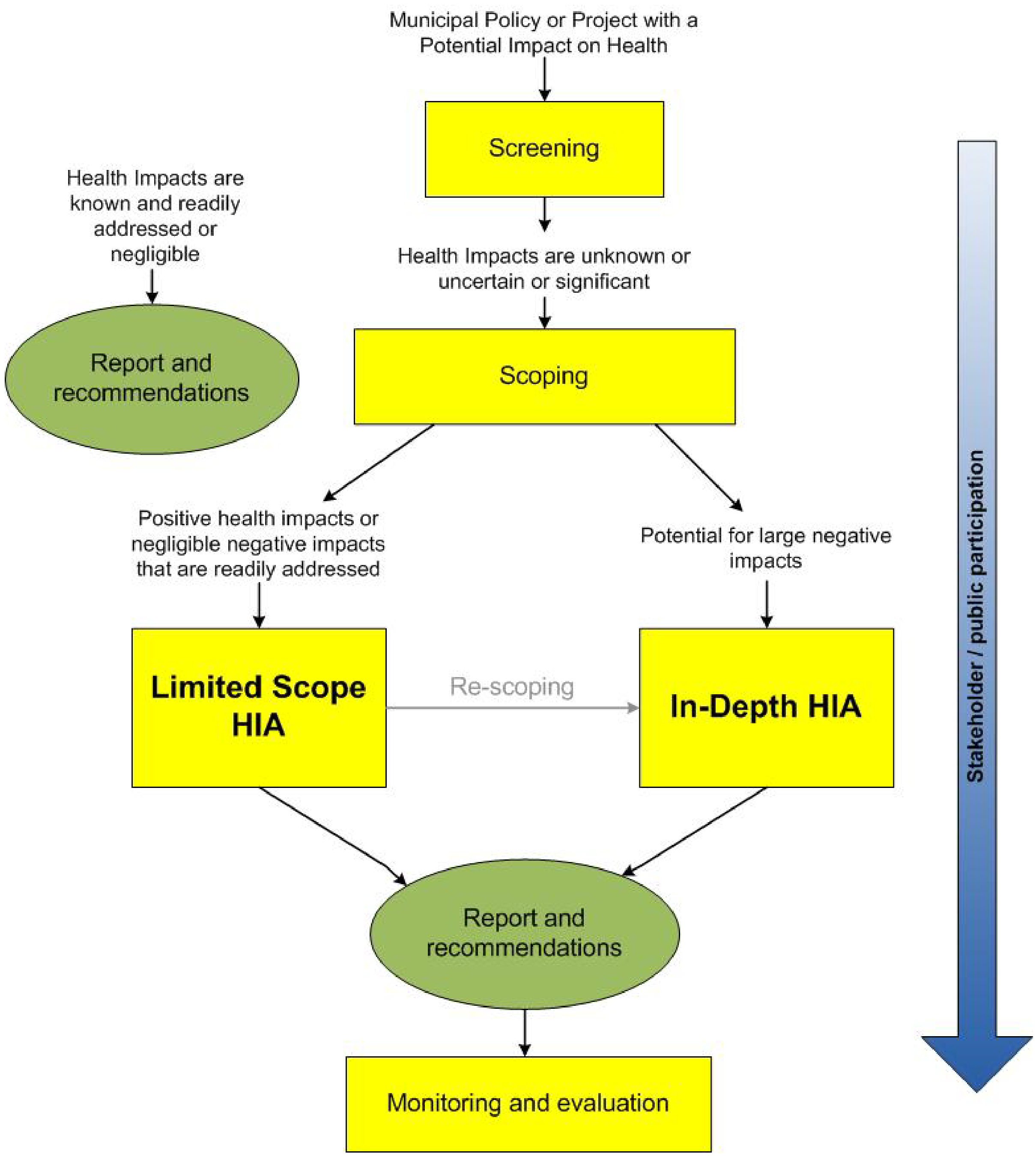


Figure G.3 *Proposed TPH HIA process*

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