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Analyzing Prediction Methods for Atmospheric Dispersion of Pollutants from Incineration: Three Canadian Environmental Assessment Case Studies

by

Michelle Fromme-Marcellin

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A thesis

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Requirements for the degree of

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Title: Analyzing Prediction Methods for Atmospheric Dispersion of Pollutants from Incineration: Three Canadian Environmental Assessments Case Studies

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Program: Environmental Applied Science and Management

Institution: Ryerson University

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Abstract

Three Canadian environmental assessments (EAs) were chosen as case studies. Each undertaking is an incineration facility. The EAs are analyzed to determine their approach, methods and techniques for predicting impacts on surrounding air quality. A methodology for objectively assessing these EAs is based on a literature search, and extensive criteria are devised. The major finding of the report is the limited nature of the description of the manner in which decisions were made, the methods used for prediction, and a lack of sufficient presented data to allow a decision-maker to understand the conclusions drawn. Simple solutions are presented to improve the ability of the EA document to facilitate decision-making based on the common findings of the three case studies.

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1. Introduction

1.1. The Problem of Prediction in Environmental Assessments

Waste incineration is considered by some to be a necessity of modern, urban life, and to others, a life threatening activity. Incineration is an issue that has the ability to polarize public opinion regarding its positive and negative attributes. What is rarely disputed is that the pollutants emitted can have harmful effects upon humans, the surrounding ecosystem, and the environment more broadly. Instead, the debate over incineration tends to centre on whether the management and mitigation techniques are capable of preventing any possible harm from pollution, and whether incineration is worth the risk.

Environmental assessments (EAs) are theoretically structured in such a way as to be an ideal tool for helping to address what the likely impacts of incineration are, and place it in a local context. EAs at their best should be able to identify the salient risks to humans and the environment, identify management and mitigation tools and then determine if they mediate the risk sufficiently to allow the project to proceed.

As a predictive and decision-making tool, environmental assessments leave much to be desired. Many projects trigger the need to complete an EA. Some of these projects are environmentally benign, and some, such as the creation of a new incinerator, pose potential environmental and human health concerns. For the protection of both environmental and human health, it is imperative that the efficacy of environmental assessments be ensured. Incineration, given its possibly significant adverse impacts, makes for an interesting type of project to assess the ability and methods environmental assessments use, as a process, to protect environmental and human health.

Briassoulis (1995) has suggested that some EAs may not consistently predict the consequences or assess the acceptability of incinerator project impacts (Briassoulis 1995). For the prediction of air quality impacts, the particular focus in EAs is in the use of models to predict the concentration and dispersion of contaminants. An important component of EA is prediction, yet predictions may vary in the accuracy with which actual conditions are forecasted. Thus, EAs have to be judged on other, less scientific, criteria. However, before such a discussion can be developed in greater depth, it is necessary to present a brief overview of the environmental assessment process.

1.2. The Environmental Assessment Process

Environmental Assessment legislation was first created in the US in the early 1970's to prevent the avoidable and unacceptable impacts of public sector projects (Noble 2006). Environmental Assessment (EA) is a process for evaluating the merits and impacts of a project in terms of environmental considerations. Since its inception, the practice of conducting EAs has spread to numerous countries worldwide (Wood 1999). Canada followed the American example and created its own environmental assessment legislation in 1973. The province of Ontario was the first to create EA legislation at the provincial level, and did so in 1975 (*SBC 2002, c. 43*).

The environmental assessment process is fundamentally an approvals process, with defined triggers to initiate it, and structured steps and responsibilities for both the proponent and the regulatory authority to complete. While definitions of environmental assessment vary, there remain consistent references in academic literature that the environmental assessment approvals process has the overarching goals of environmental protection, and sustainable development (Gibson and Hanna 2005). EA is intended to achieve these broad goals by ensuring that identified environmental factors are considered in the project decision-making process by comparing them against what is considered to be unacceptable environmental damage or change. Determining what is unacceptable environmental damage is by no means a trivial task.

There are a number of EA jurisdictions in Canada, and each of them varies in its approach to the execution of the EA approvals process. The specifics of the process may differ, but the general procedures are far more similar than dissimilar. The following is a bare bones attempt to give an overview of the common steps and elements present in most EA jurisdictions in Canada. To illustrate how a particular concept has been implemented, examples from particular EA legislation will be given.

There are a few commonly necessary steps in the EA process in Canada. The first step is initiated when a particular undertaking triggers EA legislation. Not all projects or undertakings initiated in Canada are required to go through the EA process. Each jurisdiction, be it federal, provincial or territorial, has a particular set of circumstances or undertakings for which an EA will be required. Taking the federal EA legislation as an example, there are four main ways that an EA is required under federal jurisdiction. A federal EA must be completed if: a federal authority proposes a project; a federal authority provides financial assistance for a project; a federal authority sells, leases, or transfers control or administration of land with the intent of allowing a project to be undertaken; or a federal authority issues a permit, licence, or approval for a project to proceed (*1992, c. 37, C-5.2* 1992, Herring 2005, Noble 2006).

Furthermore, in these circumstances, an EA will only be triggered if there is likely to be significant environmental impact from the undertaking. A jurisdiction may also employ two ways of limiting which projects require an EA. There can be a list of types of projects on an 'exclusion list' or the Minister of the particular environmental jurisdiction may exempt a project from being required to complete an EA. Some examples of projects on the federal exclusion list can be generalized as those that are undertaken when Canada is in a state of national emergency, for national security reasons, or projects that are considered to be routine and not expected to cause significant adverse environmental impacts (Noble 2006).

Once the EA has been triggered, the next step in the process is to determine to what level of detail the impacts will be examined in an EA. In the federal case, there can either be screening reports or comprehensive reports. The main difference is the level of detail, and the number of environmental considerations that are included. As the names imply, the comprehensive report is the more detailed of the two. If a comprehensive EA is required, the typical next step in Canadian jurisdictions is the completion of a 'terms of reference' (ToR) document. Like the final EA document, the Minister of the Environment for the relevant jurisdiction must approve the ToR. To ensure that a submitted ToR is approved, ToR documents may be created with the input of the regulatory authority.

The 'terms of reference' document acts to provide clear guidelines to the proponent of the project regarding what must be included in the final submitted EA document. It may also include timelines for when steps of the EA process will be completed, and if and when the public will be able to comment. There are a number of specific considerations that a

ToR must address. Taking the Ontario EA legislation as an example, the ToR must include (Graci 2005):

- The purpose of the project;
- Rationale for the project, and alternatives to and alternative methods of carrying out the project;
- Discussion of the environment to be affected, directly or indirectly, and any ways to mitigate those effects;
- Discussion of the evaluation of the advantages and disadvantages pertaining to the environment, of the purposed undertaking and the previously outlined alternatives;
- Discussion of the consultation process.

A discussion of the environment to be affected includes a description of baselines for environmental conditions, and impact identification. Impact identification is a part of the scoping process of EAs. Impact identification is a decision of which aspects of the environment and the project will be considered in the EA process, and which are considered to be environmentally benign and, therefore, not necessary to study in detail. An evaluation of advantages and disadvantages includes impact prediction and measurement, as well as a discussion of the management and mitigation techniques to be employed in the preferred project scenario as well as each of the alternative scenarios. Impact prediction is the critical step in the EA process. It is where methods of estimating the consequences of a project such as an incinerator have to be chosen and applied to determine the nature of its impacts. Impact prediction takes into account the data gathered from baseline studies, and predicts what impact the project will have on the environment to be affected, both if the project were to take place, and if it were not. Measurement is the gathering of any relevant data in the surrounding environment. Management and mitigation both relate to the methods employed in the construction and operation of the project to avoid as much adverse environmental impact as is necessary, possible, and feasible under time and financial constraints.

Once the proponent of the project has completed the EA document by following the ToR, the document is submitted to the Minister for approval. During this process, there may be a chance for the public to participate in the process. Canadian jurisdictions vary in the specifics of how public participation is executed, but often this may mean giving the public a specified amount of time to submit comments regarding the ToR or the EA document. Once the document is submitted to the Minister, typically the Minister has a set amount of time in which to consider the submission, and rule on whether or not it is approved.

This is the basic process by which a project triggers and completes the EA process to be approved by the Minister. Depending on the jurisdiction, there may be avenues for the public to request that a project not be approved, or to be required to conduct an EA if it would normally not have to. However, instances where either of these publicly led initiatives has occurred are rare compared to the number of EAs following the standard route just outlined. The central element is the choice of prediction methods and their estimation of their effects. If the predicted impacts are unacceptable, the project can be rejected.

1.3. Impact Prediction

If the goal of EA, as purported above, is environmental protection by influencing decision-making, an important question is not only how the EA process can or should influence decision-making, but also whether the EA process, as it exists today in Canada, is capable of influencing decision-making to meet this goal. As outlined briefly above, there are many aspects to the execution of an environmental assessment. One of the more fundamental steps of the process is the necessity for a proponent to predict the impacts of the proposed undertaking on the environment to be affected. Nowhere in the EA process is the difficulty of execution more apparent than in the attempt of impact prediction; however, in general, there is limited guidance as to how predictions should be executed.

Prediction is by its very nature a scientific process. As it is a required step in the EA process, this highlights one important question in the execution of an environmental assessment – how should science be incorporated into the environmental assessment decision-making process? The guidelines provided by the regulatory authority are largely silent on this matter. Little help is provided when approaching the application of science to the problem of prediction in environmental assessments. Possibly as a result of this, predictions in environmental assessments been described as not being very reliable (Briassoulis 1995). Studies analyzing the accuracy of prediction have found them to be not particularly successful, and on the whole not much better than chance (Briassoulis 1995).

Thus, the question of the application of science to address environmental assessment prediction is an important one. Academics hold greatly varied opinions on this topic as is evidenced by the literature. One extreme position is to purport that it is necessary for science to be applied in as rigorous a manner as possible to complete impact prediction. Such a view would require extensive time and money dedicated to the project. Experimentation, modeling, sampling, and the use of specialized equipment and numerous trials could be integral, any one of which could surpass the time constraints of the proponent.

Take incinerator EAs as an example. Incinerators are by definition point source emitters, and the atmospheric impacts must be predicted despite the complex nature of the atmosphere. Atmospheric movement and pollutant dispersion is a stochastic process. Given the possible constraints of time and money placed on the proponent when predicting impacts; there are a limited number of tools that can be used in atmospheric impact prediction. Therefore, regular hindrances to prediction are compounded when considering the difficulties of applying air contaminant dispersion models in EA prediction. The following section addresses how the difficulties and limitations of atmospheric dispersion modeling interact with the difficulties and limitations of EAs.

1.4. Atmospheric Dispersion Models and Impact Prediction

Predicting impacts is by its very nature an uncertain and error-prone process, and yet it is one of the most important and fundamental aspects within the practice of environmental assessment. There are many different methods to predict the impacts from a particular proposed undertaking. For atmospheric dispersion, the most common method is the use of a Gaussian dispersion model (Moussiopoulos, *et al.* 1996). With each method of prediction, there are associated difficulties, which arise in a variety of uncertainties. Atmospheric dispersion modeling is no different. In fact, it is incredibly difficult due to a number of factors described below. Should this initial premise postulating that atmospheric prediction is extremely problematic be unconvincing, consider just how hard it is to predict the weather accurately even in the not too distant future. This section outlines the numerous ways that uncertainty and error can occur in air quality prediction for a point source such as an incinerator.

Gaussian models are a type of model rather than a specific model. As a group they are used to predict atmospheric dispersion from a point-source emitter. They do this by modeling atmospheric dispersion in three dimensions by employing inputs to characterize atmospheric movement. The inputs required for Gaussian models are outlined below, and Figure 1 illustrates simplistically how wind speed and averaging predict air quality.

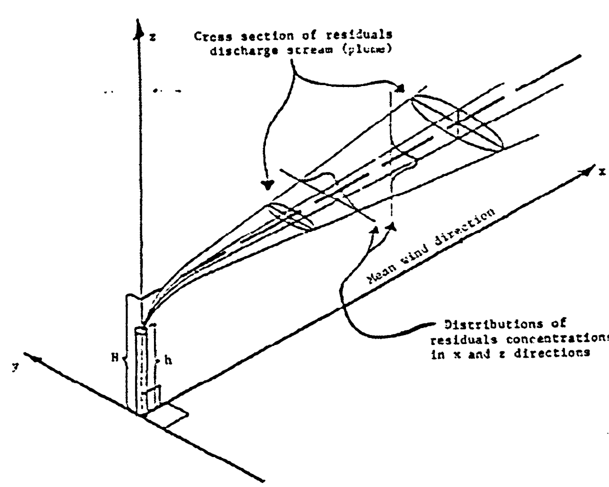

Figure 1. Gaussian Plume (Basta and Bower, 1982)

Meteorology is a stochastic process and predicting any number of the atmosphere's characteristics is remarkably error-prone. Yet, local meteorology is a primary factor determining the way emissions from a point source disperse (Fox 1980, Fox 1982, Rao and Husker 1993, Romanowicz, *et al.* 2000, Weil, *et al.* 1992). As such, several aspects of meteorology are input into Gaussian equations. The common meteorological factors that are considered in most Gaussian equations are (compiled from: Cimorelli, *et al.* 2005, Moussiopoulos, *et al.* 1996, Rao and Husker 1993, Seaman 2000, Weil, *et al.* 1992): horizontal and vertical mixing ratio, cloud fraction, liquid water content, precipitation, boundary layer depth, turbulent intensity, surface heat flux, surface moisture flux, surface momentum flux, wind speed and direction, atmospheric stability, vertical profiles of velocity, temperature, friction velocity, surface roughness, solar heating, albedo, and surface wind shear.

Not all of these factors, or aspects of meteorology are input as raw data from monitoring sites. Some meteorological parameters are calculated within the model itself. AERMOD, a commonly used Gaussian equation, for example, uses its meteorological pre-processor to calculate the atmospheric mixing height from the component inputs of cloud cover, morning upper air sounding, surface wind speed and direction, and temperature (Cimorelli, *et al.* 2005). However, parameters such as wind speed and direction and temperature cannot be calculated within the equation and must always be supplied.

The characteristics of Gaussian equations, given that some parameters are calculated within the model while some are not, have implications for the uncertainty associated with the equations' outputs and error propagation within the model. This topic will be elaborated on briefly below.

A number of authors have written papers dedicated to the discussion of uncertainty in atmospheric dispersion models: Moussiopoulos et. al. (1996), Fox (1980, 1982), Romanowicz et. al., (2000), and Rao (2005). Atmospheric dispersion models are no different from any other models in that they are fundamentally a simplification of reality, and therefore, inherently error-prone and subject to uncertainty in their results.

There are two ways in which the accuracy of the atmospheric dispersion model are affected. Both the input parameters and the model itself are simplifications of reality. Data inputs are simplifications in terms of spatial and temporal resolution. Many meteorological parameters used in Gaussian equations can change rapidly and often, with wind speed and direction as critical examples. Practitioners are not able to gather sufficient data points, temporally or spatially to accurately represent reality. Gaussian equations address this problem by using ensemble values, essentially averages as representative data points of reality (Weil, *et al.* 1992). Therefore, instead of having instantaneous data inputs, there are time averages instead.

Wind speed is an example. As mentioned above, velocity and direction data can be used to calculate other variables within the model. Therefore, the input of wind speed in the model will represent more than just the specific place where the measurement was taken, or that specific moment. Instead, that measurement will be used to represent a larger time and space than it can accurately represent. The broad assumptions here are that diffusivity, wind speed and wind direction are essentially constant over the time they are averaged. This is not the case. The result of these simplifying assumptions is that the equation has certain predictive limitations as to the time and distance that are predicted. Romanowicz et. al. (2000) and Rao (2005) both estimate this limitation to imply that the equation should not be used to predict more than an hour in time or 30 km in distance. Not just these data inputs, but every data input into a Gaussian equation, will increase the error of the model due to its simplification of reality.

The Gaussian model uses knowledge of atmospheric movement with topography and emissions to try to predict what the concentration of a pollutant, or series of pollutants, will be at a given time, and point. There will always be uncertainty associated with such a complex model. Moreover, the long list of possible inputs to a Gaussian equation is by no means a definitive list. Different models have differing levels of complexity and use different parameters to model atmospheric physics. Rao (2005) makes an interesting observation regarding the complexity of atmospheric physics modeling in equations. He points out that the total uncertainty of a model has an optimal point, (Figure 2).

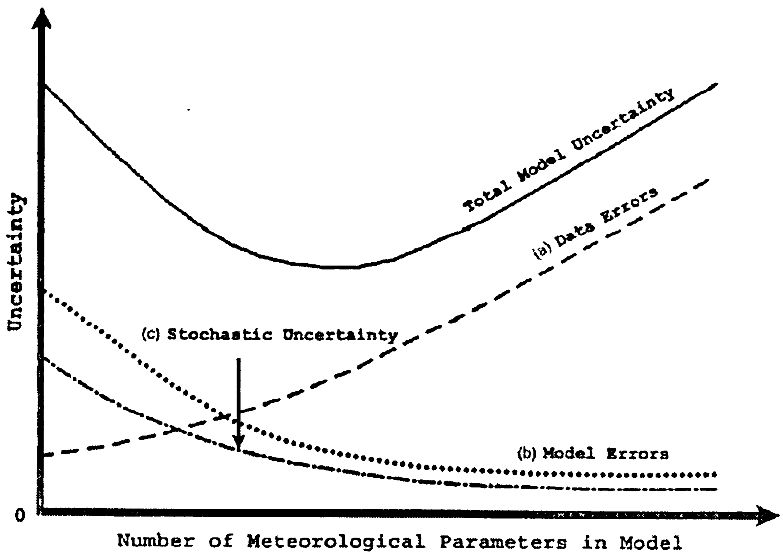

Figure 2. Components of Model Uncertainty

The simpler the model, the less capable it is of accurately representing real atmospheric physics. Therefore, in simple predictions, the model uncertainty is high, and the data or parameter uncertainties are lower because there are fewer variables. The parameter uncertainty is lower because there are fewer parameters in the simpler model. As the complexity of a model increases, as does its ability to more accurately represent atmospheric physics, the number of variables increases. Thus, the model uncertainty decreases, but the data or parameter uncertainty increases.

To continue with the idea of reducing uncertainty (and error) in a Gaussian equation as much as possible, Rao and Husker (1993) and Fox (1982) have discussed aspects of Gaussian equations in terms of reducible and irreducible uncertainty. Reducible uncertainties and errors are those that it is possible with the advance of science and technology to improve on. The aspects that fall into this category are parameter measurements or input data, errors in concentration measurement either in ambient measurements or emissions data, and internal model errors and the modeling of physical processes. It is possible to decrease the error/uncertainty introduced into atmospheric dispersion prediction by improving the techniques or equipment employed to measure such data inputs.

Irreducible error/uncertainty types are aspects of prediction where there is no hope of eliminating the uncertainty. This concept recognizes the immutable existence of chaos in atmospheric processes – there will always be an element of the stochastic in any measurement that cannot be predicted or reduced. The fact that there are these considerations in atmospheric dispersion prediction gives adequate example of just how complicated atmospheric dispersion model applications are in real world situations with the number of variables, and details that are too small to be accurately modeled and represented in the model outputs.

A further source of error and uncertainty due to parameter input into Gaussian equations is that of emissions data. This input is crucial in the estimation of pollutant concentration at receptor sites. Emissions data are subject to many different kinds of variability. Production factors that can change the emissions concentration from an incinerator are: incineration feed, incineration fuel, and variations in production level (Fox 1982). Unlike meteorological data, emissions inputs are not based on sampled data. They are typically based on the theoretical approximation that the emissions from an incinerator will always be the maximum concentration release allowed for that particular facility. Sometimes the emissions data will be based on monitored/observed values from another, similar facility such as the KMS Peel EA (KMS Peel Inc. 2000).

Up until now, this discussion has focused on how error and uncertainty are introduced into a Gaussian equation by parameter inputs and the model itself. The total uncertainty in the model's output is not the mere sum of all the errors/uncertainty noted thus far. Input errors and uncertainties are propagated throughout the model and the final error and uncertainty will be markedly different than the inputs. This is easiest to understand when considering that the basic meteorological input to a Gaussian equation is also subsequently used within the equation to calculate another meteorological parameter. The initial input parameter's error and uncertainty will be passed onto that new calculated parameter. For example, heat flux can be calculated using more than one meteorological input. Each of those input variables will have its own associated error and uncertainty. Therefore, calculating the likely error and uncertainty of even an internal parameter of the Gaussian equation is not a trivial task.

As this is far from a new problem, sensitivity analysis has been used to quantify and analyze uncertainty in Gaussian equations. The basic principle of sensitivity analysis is to hold all but one input constant and vary that one input (Rao 2005). The resultant outputs of the equation under this test will give an analyst an idea of how sensitive the model is to fluctuations, minute or otherwise, in that particular parameter. This exercise is completed for all parameters of concern. It is a sign of a poorly applied equation if the output varies significantly with only very small changes of one variable under this test. In the case of Gaussian equations, sensitivity analyses have indicated significant variations in outputs for several variables used in impact prediction.

There is no getting around the fact that uncertainty and error are present in atmospheric dispersion impact predictions. Those uncertainties have the capacity to be significant, and as air quality has the ability to significantly impact human health, it is imperative that this error and uncertainty are addressed and not ignored.

1.5. Impact Prediction Execution in Canadian Incineration EAs

As research literature has shown, when management decisions are expected to be based on environmental science confidence must be maintained, however, questions are suggested by the process of EA usage and the expectations for the results. Not the least of these is the scientific basis for the predictions and in particular, the recognition of uncertainty. As such, this thesis will examine the means used to predict air contamination outcomes in Canadian facilities, and the manner in which science was applied.

1.6. Hypotheses

Based on the literature, it is hypothesized that the scientific content of EAs will have deficiencies in terms of how science is presented. This follows from the recognition of uncertainty in the scientific community but the reluctance of EA practitioners to provide such details when submitting their reports for public scrutiny:

- Predictions are based on results obtained from using a Gaussian dispersion equation;
- Discussion regarding uncertainty or risk associated with the predictions will be limited;

- Limited data for a decision maker to make an informed decision is presented;
- Little explanation is given regarding data quality;
- Little explicit discussion is made regarding steps in the predictive process, or how decisions were made.
- No background research is presented on other related EA undertakings

The following section outlines the procedural context surrounding these hypotheses since waste incineration has the prospect of being especially controversial. Its history includes open-air fires with disturbing local effects, yet landfilling as currently practiced is not considered sustainable.

2. Context

2.1. Incineration

The issue of whether incineration is an appropriate or acceptable way of managing waste, either municipal solid waste, or hazardous waste, is the subject of much debate (National Research Council (U.S.) 2000). What researchers of the subject are seeing is that there is protest over siting of contested technologies, such as incineration, and a rising concern regarding environmental degradation (Inhaber 1997, Kuhn and Ballard 1998, Ladd and Laska 1991, Pushchak and Rocha 1998, Rabe 1994). For both the siting of landfills and incineration facilities, at the community level, a 'not-in-my-backyard' (NIMBY) backlash is seen. This occurs publicly when a community of citizens, sometimes referred to as a grass-roots organization, work together in a variety of ways to express their collective concern regarding possible environmental risks and uncertainty associated with incineration facilities (Ladd and Laska 1991).

There tends to be a larger outcry against incineration projects than landfill sitings because of their perceived risks, stemming, in part, from the technology being not as well understood by the general public. As Elliot (2003) discusses, there are four main reasons that will cause people to judge risks more harshly, which could explain this difference. Affected populations perceive risks to be greater when impacts are seen as involuntary, inequitable, potentially catastrophic, or not well understood. All of the contributors to harshly judging risks that Elliot mentions can be applied to incineration. An incinerator may pose an involuntary risk because a community may feel that it does not have a choice, or its concerns are not being addressed and inequitable because an incinerator may be placed in a different location than that where the waste, municipal or hazardous, was created. Incinerators are potentially catastrophic due to the nature of the chemicals released, and not well understood by the public.

While it is true that some North American communities have embraced incineration, a number of other communities have worked hard to cancel, shutdown, or otherwise delay the construction of an incinerator as long as possible in their area (Ladd and Laska 1991). However, even though there is often significant public outcry against a new incineration facility's construction, governments, municipalities and private operators continue to undertake the lengthy siting process for this technology.

Opposition by residents is understandable as some of the pollutants emitted from incineration stacks have been shown to cause various adverse health effects (National Research Council (U.S.) 2000). What proponents of incineration would argue, however, is that the negative health effects associated with the pollutants are ones that were caused by exposure to those chemicals at higher concentrations than those emitted from an incinerator (National Research Council (U.S.) 2000). The uncertainty about those risks arises when trying to assess what the ambient concentrations will be when deleterious stack emissions are combined with pollution from other local sources. The public may then question the regulator's ability to ensure public health in the face of such uncertainty.

This may have, in part, caused what Mitchell (2004) suggests that citizens who feel strongly about incineration want to be a part of the decision-making process. To do this either an individual citizen, or a citizens' action group may attempt to lobby the government to support decision-making that addresses their priorities. Furthermore, it has been shown that citizens are not just interested in *what* decisions are made, but also *how* they are made (Laird, 1989). This is one reason why risk communication with the public in an EA places great emphasis on explanations of predicted impacts.

As Drew and Nyerges (2004) argue, transparency becomes critical in these issues. They purport that it is necessary when a decision is intended to protect public health and safety, as any decision regarding an incinerator should, and especially one that has long-term consequences, that transparency about impacts is important. Impact transparency is essential as it promotes improved access to information as a way to build public confidence in the decision process and strengthen credibility. For an EA report to be considered transparent, it should include a detailed description of all assumptions made in predicting impacts and in the decision-making process regarding incineration facility siting, and the factors taken into consideration in making a decision.

Decision-making for an incinerator is likely to focus on the issues of human health and environmental consequences. As for many other sources of pollutants being released into the atmosphere, it is no surprise that for incinerators the primary pathway is through the emission of pollutants to the atmosphere. The U.S. National Research Council (2000) did an extensive study into the nature of incineration, both municipal solid waste (MSW) and hazardous waste incineration, and found that there were many potentially harmful substances that were components of the exhaust gas from incineration stacks. Those substances include: particulate matter (PM); oxides of nitrogen (NOx); oxides of sulfur

(SOx); carbon monoxide (CO); dioxins and furans; metals (e.g. lead, mercury); acid gases; volatile organic compounds (VOCs); and polycyclic aromatic compounds. Once emitted into the atmosphere, people close to the facility could be exposed. Also of concern is that some of the emitted pollutants may be able to be transported for long distances if they are persistent pollutants in the environment.

Dioxins and furans are examples of persistent pollutants and often among the substances of most concern to the local public opposing an incineration facility. Both types of incineration feeds assessed in this study, municipal solid waste and hazardous incinerators, may release dioxins and furans into the atmosphere. Reference to dioxins and furans refer to polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) (National Research Council (U.S.) 2000). The same study by the National Research Council (U.S.) found that there are three possible sources of dioxins and furans:

- Un-combusted components of the original fuel (dioxins and furans are present in the materials that are thermally treated, and some quantity of this material survives the thermal treatment);
- Formation from the thermal breakdown and molecular rearrangement of particular precursor compounds;
- *De novo* synthesis (dioxins and furans are created by a chlorine donor, a molecule that takes chlorine to the predioxin molecule, and the formation and chlorination of a precursor).

Waste incineration technology and emission control have improved over the years (National Research Council (U.S.) 2000). A great variety in pollutant concentrations emitted from incineration facility stacks has been found depending on the age of the incinerator and the technology employed. For example, the concentrations of dioxins and furans can be reduced substantially by the use of a carbon sorbent bed, or by injecting activated carbon into the flue gas (National Research Council (U.S.) 2000). The most common method currently used is carbon injection. This means that small activated carbon particles are injected into the flue gas. These carbon particles are able to adsorb the particles of dioxins and mercury onto their surface because of their high volume to surface area ratio (National Research Council (U.S.) 2000). The activated carbon molecules along with the adsorbed pollutants are then captured in the air pollution control device (National Research Council (U.S.) 2000).

The manner in which humans are exposed to pollutants emitted from incinerators is complex as there are many different pathways that depend upon a multitude of factors. For the most part, incinerator exhaust pollutants do not remain in the air but, through the process of deposition (either wet or dry), can be present on the surface of soil, vegetation or water and thereby come into contact with people through their exposure to those surfaces (National Research Council (U.S.) 2000).

In both the US and Canada, often one of the requirements for an incineration facility approval is its compliance with Environmental Assessment (EA) regulations. Within the context of incineration facility siting and approval, EA can find itself the staging ground for battles between different interest groups over the risks and benefits of incineration.

If it is considered that the primary concern of the potentially affected public is human health and environmental protection, the EA study and subsequent report should prove safety scientifically to the researchers themselves, and then adequately communicate the risks and benefits to the public in the report. This becomes a difficult task when one considers that not all of the substantial amounts of data gathered and analyzed through the EA process will or should make it into the EA public report. The relevant question then becomes, how much data and information are required to ensure proper communication of risk and explanation of methods and techniques without unnecessarily making the EA document cumbersome and increasing the resources required by the proponent to complete the EA process and document. Risk communication should be a necessary part of the EA report document but not everything can be included, thus content and language are extremely important.

As the primary pathway for pollutants to travel from incineration to receptors is through the atmosphere, it is impacts from exhaust emissions that are of most importance in determining environmental and human risk. As Pielke (1998) describes:

> the assessment of outdoor air quality requires the linkage of analytical and modelling tools from several scientific disciplines. Specifically, emission inventories, transport, dispersion, and deposition factors, and chemical reactions all need to be quantitatively evaluated.

Accurate quantitative prediction of any one of those is a very complex undertaking. In the end, it must be realized that all models are uncertain to some degree. To acknowledge this fact, as well as the need to aid in informed decision-making, Beanlands and Duinker

(1983) suggest that an EA public document must explicitly state any assumptions upon which predictions are made.

Furthermore, to address uncertainty requires that predictive conclusions drawn include statistical confidence limits and probability analysis (De Jongh 1988). This needs to be done during the researching stage, as well as included in the EA document. As indicated previously, uncertainties in atmospheric processes such as the ones involved with incineration can be great but should be reported as part of the EA decision.

The importance of addressing uncertainty in EIA has also been discussed since the 1980s (Beanlands and Duinker 1983). De Jongh (1988), and indeed the U.S. National Research Council (2000) purport that only when uncertainty and variability are taken into account, are effective decisions regarding siting, design, and the operation of incineration facilities possible. As was discussed earlier, there will always be some uncertainty remaining regarding predicted atmospheric transport and dispersion (De Jongh 1988).

The question that still needs to be answered is how to deal with unavoidable uncertainty in EA. Canter (1996), after reviewing the status of prediction in EA, had several recommendations to address uncertainty. He suggested there was a need for development and appropriate use of more scientifically defensible impact prediction techniques, including those that yield a range of predictions and associated probabilities for those predictions to occur. He noted that there is a need for impact prediction techniques that address uncertainty and limitations of predictions. He also recommended that reports include techniques that enabled sensitivity analyses of the influence of input data.

The recommendations that Canter outlined are all analyses that need to take place in order that incineration decisions are well founded and based on solid scientific reasoning. Yet, this does not address the need to then communicate these risks to the public. Adequately informing of the public is a necessity in the EA process, and it is especially important with incineration as there is a chance the local population may be wary of an incinerator operating nearby. Successful risk communication facilitates public confidence by having them see that proponents are acting in good faith and by allowing people to understand how the decisions are made. Effective risk communication includes information regarding both the risks and benefits of an action. More specifically in terms of addressing uncertainty in prediction in EA, it means summarizing the relevant science (Fischhoff 1995).

The science involved in addressing uncertainty in prediction may seem far too complex for a lay person. The problem often is that an expert may take too much scientific explanation out of the EA report, thereby raising greater concerns for the public. As Lundgren and McMakin (1998) argue, if the risk message is simplified too much, the greater problem arises of leaving out precisely the key information that an interested public would rely on to make an educated decision. What they argue should be done is to simplify the way that content is presented, rather than limiting the content. They believe that it is possible for any subject, regardless of how technical, to be understood by the public, with the loaded caveat that it be presented properly. This will not mean that a public will understand it to the same degree as an expert in the field, but they should certainly have to tools for informed decision-making.

The topic of uncertainty analysis in prediction, and the subsequent communication of risks in EA is not a new topic. Much has been written about the need for this to be a part of the EA process. What seems to be lacking, however, is significant evidence that EA practitioners are moving in this direction and a simple framework that outlines specifically how this might be accomplished. The following section, use the literature to discuss possible criteria for analysis of EAs.

2.2. Analysis Criteria

Any systematic analysis of environmental assessments necessitates the creation of criteria on which to base the analysis. This is no straightforward task. The focus of this thesis is the analysis of the prediction of air quality impacts and their associated methodology in environmental assessments. This section begins by briefly discussing some of the reasons for possible variability in atmospheric impact prediction, and uses the literature to define six broad criteria to assess the acceptability of predicted impacts in the EAs.

Prediction is an imprecise science. The complexity of air quality impact prediction usually requires that there will be more than one method used in the prediction methodology. For example, a particular Gaussian atmospheric dispersion model may be a powerful tool when trying to predict short-term, flat terrain impacts, but that same equation may be insufficient when attempting to model long-term, rough terrain impacts. It is reasonable to suppose, as Shopley and Fuggel (1984) have argued, there is not one method that can be applied successfully to a large number of cases; however, they believe that it is possible to combine methods and techniques to meet any particular requirements of a situation.

The vast number of possible methods and techniques means that there can be great variety between impact methods in environmental assessments. The Province of British Columbia recognizes this outright as is evidenced by their document Summary Guide to the British Columbia Environmental Assessment Process (British Columbia Environmental Assessment Office 2003). The document outlines how the regulations only serve to establish a framework for completing environmental assessments. All of the scoping, procedures and methods specific to any environmental assessment should be tailored to that particular situation. The document purports that this allows each environmental assessment to focus on the important issues relevant to whether it should proceed. This takes a rather positive view of the regulations' effects, without considering any problems that might arise from the lack of guidance in completing an environmental assessment.

British Columbia is not the only jurisdiction that is structured this way. The flexibility of environmental assessment regulations to fit each project individually is a tenet of general environmental assessment theory. Cashmore (2004) argues that the power and success of environmental assessments is recognized precisely because it is a flexible tool able to adapt to differing biophysical, socio-economic and geopolitical situations. One definite result of the lack of guidance for prediction is that variations in methods and techniques used in EA add to the complexity of devising appropriate criteria for analysis.

Therefore, in order to select criteria for the analysis of air quality impact prediction, a number of sources were employed. Weston (2000) makes a valuable point when he argues there that is "no absolute 24-carat gold standard by which a decision can be judged right or wrong." With this in mind, the following section strives to bring together wisdom pertaining to EA assessment found in the literature and, a brief discussion is provided about the more common analytical techniques. This is done to determine their applicability to the creation of an analysis tool for air quality impact prediction.

To create an environmental assessment that is capable of accurately predicting environmental impacts requires a thorough understanding of the environment to be affected. There must be adequate baseline data with which to compare predicted impacts and to determine significance. There must be the application of sound science in the creation of impacts, and use of experts to carefully consider the effects on human and environmental health. These could include the tasks of managing and mitigating those impacts combined with a monitoring program to assess how well the undertaking in operation is meeting any relevant standards, and how accurate the predictions were. This is an extremely broad-brush description of the steps for completing an environmental assessment.

Many authors have outlined the fundamental steps of completing an EA – all with their own slight changes in terminology and emphasis. The following description of Harrop's steps for completing an EA is not to be considered the pinnacle of a description of this aspect of EA, rather the manner in which it is explained lends itself easily to the emphasis and understanding of the needs of prediction within environmental assessment. Harrop (1997) describes a series of events that occur in the completion of an EA. The pertinent steps he outlines are: impact identification; impact prediction and measurement; impact description and evaluation; monitoring; and presentation and communication of information to decision-makers. What is not addressed in these five, but a necessary consideration for prediction of impacts, is a discussion of managing and mitigation measures for predicted impacts, a step that can be considered to come after impact description and evaluation in the timeline of environmental assessment events. 'Presentation and communication' are not discrete sections within an EA document as are the others just mentioned. As such, these criteria will be discussed for the EA document as a whole, as well as for each of the five sections that form the basis for the other criteria.

Intuitively, the concept of presentation and communication are easy to grasp, but defining easily understandable criteria to illustrate these issues is somewhat harder.

An EA document must be well organized, and presented in such a way that lay readers and decision-makers can follow the steps, choices, and conclusions drawn. The decisions made, and methods and techniques used must be explicitly addressed and explained. This is necessary, as Glasson (1999) states because being able to influence decisions about projects is at the heart of environmental assessment. Glasson believes that environmental assessment must first be a process whereby projects can be improved through a decision-making process that is able to influence the planning, design and implementation of a project. Achieving quality decision-making requires transparency and good presentation throughout the EA document. Transparency increases the reliability of the decision-making process.

Not surprisingly, ensuring sound decision-making also requires an adequate amount of information and for that information to be free from bias (Fuller 1997). This idea has been described by different people in a number of ways – all with the same purpose of environmentally conscious and reliable decision-making. For example, Sadler (1996) discusses a best-practice EA process in terms of the 3 A's: Appropriateness (coverage of key issues and impacts), Adequacy (of impact analysis), and Actionability (does the report provide the basis for informed decision-making?). Ross (1987) uses three questions for the same purpose:

- Is the EA focused on key questions for decision-making?
- Is the EA scientifically and technically sound?
- Is the EA clearly and coherently organized and presented so that it can be understood?
- These ideas and questions raised provide the criteria for assessing presentation and communication throughout the selected EA documents.

Combined, the six broad steps of the criteria are: Impact Identification; Impact Prediction; Impact Description and Evaluation; Management and Mitigation, and Monitoring. Together, these six different steps will be used to group different prediction tools together for discussion, and form the backbone set of criteria used in this thesis. These six are broadly related to stages of the environmental assessment process; however, some criteria that will be included in the assessment cannot be confined to a particular section, or phase in the environmental assessment process. These criteria will be discussed after outlining the criteria that can be placed into discrete phases of the EA process.

2.2.1. Impact Identification

Impact identification is often referred to as the scoping stage in the environmental assessment process. It involves selecting the aspects of the environment that may have the potential to be significantly negatively impacted. This is a fundamental precursor step to impact prediction as Meredith (2004) argues that it is necessary to know the components of the environment if the proponent is going to be able to predict impacts. No EA is capable of including a discussion and prediction of all possible impacts so key impacts have to be chosen. Scoping is one of the most fundamental and important aspects of the environmental assessment process, for if the 'correct' issues are not identified the quality of the environmental assessment will undoubtedly suffer greatly, while at the same time inhibiting the ability of adequate decision-making (Weston 2000). This is supported by Meredith (2004), who argues that it is essentially impossible to achieve complete knowledge of an environment, and generally there is a steep incremental cost of acquiring increasingly precise information. Finance versus information gain is, therefore, one obvious criterion for determining the scope of an EA.

Baseline data are a part of impact identification. The important impacts that are identified are likely those that will be monitored at their baseline levels, with the data being incorporated into the prediction step. Beanlands and Duinker (1983) note that baseline data are meant to be data that represent the conditions of the environment before the proposed project occurs; and to do this successfully, those data must consist of statistically adequate representations of the natural variability of the chosen environmental components.

If there is already a resource of baseline data, as there often is for air quality, it can influence the choice of indicators. Conversely, if there are important indicators that must be included in the environmental assessment, the proponent may conduct their own baseline analysis. Usually the environmental assessment will necessitate gathering baseline data; however, air quality is unusual in that there is often a source of historical data – airports being a common source of this. Ambient air quality monitoring is common, and if a proposed incinerator location is close to such a monitoring site, the data gathered there over the years would be very useful. Cities are more likely to have monitoring stations than more rural locations. Also, the chemicals monitored at a local monitoring station may not measure all of the chemicals in which a proponent is interested. Caution should be taken when using historical data. They should not be allowed to entirely dictate the choice of indicators, but rather used as a resource once the indicators have been chosen. This is especially the case for incineration, as often there are no historical data for such relevant pollutants as dioxins. As noted above, airports are a common source of information, but they do not monitor pollutants like dioxins.

Elkin and Smith (1988) outline some key aspects of baseline data gathering. These are broken down into "describing baseline conditions" and describing "natural fluctuation and human influence." The questions Elkin and Smith raise for baseline conditions that should be addressed are:

- Does the report adequately describe existing conditions of key natural resources, ecosystems, and land uses?
- Does the report adequately describe relevant social and policy issues of a local nature relating to the project?
- The questions Elkin and Smith raise for "natural fluctuation and human influence" are:
    - Does the report identify variability due to natural fluctuations?
    - Does the report identify variability due to human influences, such as pollution from existing activities?

The question of bias is also raised since there are many aspects within an EA in which objectivity could be questioned. For example, "is there undue emphasis placed on particular stages of the project or on particular resources?" This could refer to the choice of chemicals assessed, or preferentially analyzing short or long-term effects of the air pollution impact. Objectivity can also be questioned in terms of the specific geographic area in which air quality impacts are predicted.

Marriott (1997) and McFarland and Nelson (2004) both deal with methodology for air quality impact prediction specifically. Marriott (1997) believes that the first step in predicting future air quality in an area is to describe the air resource characteristics of the region, including any possible impacts on climate conditions and other pollutant levels.

Harrop (1997) is more specific about the information needed for the baseline study, and highlights four specific aspects that must be included:

- The ambient air pollution concentrations, pollutant sources and their specific location relative to the proposed development;
- Local climate and meteorological parameters;
- Local topography, physical conditions affecting pollution dispersion (e.g. buildings);
- Sensitive receptors and their specific location (e.g. residential areas).

To address which key impacts should be considered and how to conduct a baseline study, McFarland and Nelson (2004) created four steps that an EA often goes through.

The first step is stating the problem. Because of the complexity of air quality impact prediction, it is often necessary to define the problem using a multi-disciplinary team to ensure that the most important aspects of the problem are addressed. This includes all the aspects just mentioned. The next step is to identify the decision. A question must be defined that the data collection effort will attempt to resolve and alternative actions must be created based on the study results. A common concern for air quality impact prediction could be 'will the concentration of pollutant X, or specific chemical of concern exceed the stipulated safe concentration guidelines for the environment to be affected?' Next, it will be necessary to identify the inputs for the decision. This means identifying the different types of information that will be needed to address the decision statement.

McFarland and Nelson (2004) have as their fourth step, defining the boundaries of the study. Defining the boundaries of the study refers to spatial and temporal components of the study. However, considering impact identification and baseline studies in light of the decision, does help to emphasize the importance of adequate data.

Each EA is analyzed based on the manner and completeness that the environment has been described. This means that the data gathered for meteorological and local conditions should be sufficient, and the data's strengths and weaknesses should be explicitly considered. Accurate prediction of atmospheric dispersion is a complex process given the vast amount of data required and the stochastic nature of dispersion. In essence, the analysis of each environmental assessment 'impact identification' will look for completeness in considering possibly significant impacts, as well as the logic applied for the selection of the boundaries of the study.

2.2.2. Impact Prediction and Measurement

After the impact identification stage of the EA process comes one of the most demanding, both technically and financially, and important sections of the EA document – impact prediction. Analyzing this complex portion of the EA document is a daunting task and an effort has been made to break up the process into manageable and easily identifiable sections that can form the basis of criteria for impact prediction analysis. As a part of this process, future conditions for the environment to be affected are predicted for a future state with and without the undertaking. To name just a few, prediction methods and techniques can range from case studies, models, literature, and expert judgment (George 2000).

In *Environmental Assessment* by Jain et al. (1993), the concept of atmospheric analysis is divided into its two most fundamental components:

- Structural elements of the environment; and
- Inputs to or emissions from human activities.

These two components are then further divided into their measurable constituent parts, and the associated data collection methods and inputs required. This particular division allows for a fairly straightforward discussion of different aspects of atmospheric analysis.

Structural and meteorological elements of the environment can be considered to be such aspects as: stability, temperature, mixing depth, wind speed, wind direction, humidity, precipitation, pressure and topography (Jain, *et al.* 1993). These are important components when it comes to the atmospheric concentration of pollutants, as they are the primary indicators of atmospheric dispersion and, therefore, used as data inputs for atmospheric dispersion modelling. They are also important characteristics in and of themselves.

For 'inputs to or emissions from human activities' there are some broad categories of data usage that need to be considered. These are:

- Use and acquisition of data (Elkin and Smith 1988);
- Sources and adequacy of information (Elkin and Smith 1988);

- Scientific rigor (Cashmore 2004, Weston 2000);
- Tolerable limits of uncertainty (McFarland, *et al.* 2004).

'Use and acquisition of data' and 'sources and adequacy of information' are interrelated. The quality and methodology associated with the use and acquisition of data will have direct impacts on the adequacy of the information produced. 'Scientific rigor', for this thesis will be used to refer to the manner in which choices are made within each of the first two individually, and their interaction together.

As mentioned earlier, the most common type of atmospheric impact prediction for pollutants from a point source is a Gaussian model. The data requirements for this type of model can also be divided into meteorological inputs and emission data inputs. The meteorological data used in the model are often a speculated 'worst-case' scenario based on local historical meteorological data. The emissions data inputs are such details as: stack height, internal diameter of the stack, flue-gas temperature, flue-gas exit velocity (or volumetric flow rate). Given the large burden of data required for atmospheric dispersion modeling, there will naturally be many different sources of data. Each data input, based on the model used in each of the selected EAs, is considered based on the source and relevance of the data. As outlined earlier, each of these inputs will have their own individual error and uncertainty associated with them. The impact of each input's uncertainty and error to the overall output can be estimated by undertaking sensitivity analysis for each of the data inputs.

For each incinerator, one question that needs to be addressed is how close and how representative are the weather data that are used to typify the incinerator location? Are the data recent enough? Do the data span a large enough time to be representative? Furthermore, the question that Elkin and Smith (1988) posed directly "is there any basis for questioning the data cited to support [the] conclusion?" It is worse than useless to use unrepresentative weather data, as the resultant output may give false confidence or concern to an incinerator's impacts on surrounding human and environmental health.

The choice of the EA's methodology for prediction, within air quality specifically, and environmental prediction more broadly, is made by specialists. It is experts that apply the three main steps of prediction: the selection of methods, the use of methods, and organization and presentation of results (Morgan 1998). There is often a lack of time and money for the completion of an EA document, and difficult choices have to be made about how prediction is undertaken. As the EA document is a decision-making tool and an informative tool for the general public, it is important that these choices are stated explicitly. Morgan (1998) outlines some of the more important aspects that must be included explicitly in this section:

- The basis for prediction must be included. Is it an expert's considered opinion or the result of intensive computer simulations? To what extent is the prediction based on experience with other, similar developments?

- When particular methods and techniques have been used, they should be identified and, if necessary, explained;

- It is important to identify any factors that constrain or limit the prediction and how it can be used. These might be assumptions that depend on a particular environmental condition and the data available.

The first two of these points deal with methodology choice and data use. The last point addresses the issue of scientific rigour and uncertainty in prediction. Holling (1978) notes that prediction about the behaviour of complex environmental systems is often counter-intuitive. He argues sensibly that it is impossible to know future events with certainty, and therefore it is necessary to develop strategies for handling uncertainty. Dealing with uncertainty is a part of scientific rigour.

To address uncertainty in prediction, Elkin and Smith (1988) argue that it is important to ensure that the prediction of impacts addresses the probability of serious effects and does so by including a degree of confidence in the predictions made. McFarland and Nelson (2004) phrase this concept in terms of "tolerable limits on decision errors."

Another proponent of the use of statistics and probability is Rao (2005). He outlines the requirement of using ensemble mean, variance, and probability distribution to describe atmospheric dispersion. Therefore, without uncertainty analysis, it is impossible to quantify the degree of confidence for an estimated risk associated with an incinerator's atmospheric pollution. The literature states that scientifically rigorous uncertainty analysis, such as sensitivity analysis, is rarely done in EAs; however, this does not mean that some attempt is not made to understand the errors present in the data, and predicted impacts.

There are few valid reasons given for the frequent omission of uncertainty analysis in EA prediction. Institutionally, given the time and financial constraints that most proponents are under when completing an environmental assessment, the proponent may chose to cut down on analysis by not completing uncertainty analysis. A methodological reason could be the large complexity of uncertainty analysis when applied to atmospheric dispersion modelling (George 2000). Further, it may reveal how uncertain the impacts may be. Whatever the reason, the absence of sensitivity analysis in EAs is not rigorous science.

For impact prediction, what was examined during the analysis of the EAs is whether there are adequate data given to allow a decision-maker to make educated decisions regarding the impact to the surrounding population. The prediction section of the selected EAs are assessed to determine whether they have explicitly state the limitations of the gathered data, and the analysis tools used.

2.2.3. Impact Description and Evaluation

Impact evaluation is primarily focused on 'significance' assessment. Many people have defined significance differently, or chosen different aspects to highlight. Sippe (1997) made the comment that while the concept of significance is a prominent one in environmental assessment theory, it has not yet been assigned a commonly understood definition for its practitioners.

It is important in EA evaluation to determine significance for two reasons, first to assess whether an undertaking should be allowed to proceed, and second, whether there need to be management and/or mitigative measures applied to the undertaking. A project may result in adverse environmental impacts, but if impacts are not significant, the project will proceed, without management or mitigation of impacts.

As was argued by Beanlands and Duinker (1983), the issue of significance holds great importance in the field of environmental assessment because at some point along the decision-making process the issue always becomes whether the predicted impact is 'significant.' While this thesis focuses on the technical or scientific aspect of significance, it does not do so by ignoring the basic fact that, as Sippe (1997) explains, significance can only be determined in light of the intensity of the impact on the baseline environment as well as the importance that environment has to the community that uses it. To address this, there have been numerous academic works that have discussed the different elements of significance.

There are many possible elements that could be considered as part of significance, but not one set that is accepted by the majority of practitioners, scholars or policy makers – as is exemplified in that every literature source found had a different definition. However, there are elements that are often found common among the descriptions of significance. Table 1 is one of the more comprehensive lists when considering the nature of significance. It is used as a starting point for the discussion of what elements should be included in the determination of significance. Bram Noble, a prolific writer in environmental assessment theory, devised it.

Table 1. Noble's Elements of Significance (Noble 2006)

Significance:	
1. Beneficial vs. detrimental	7. Geographical extent
2. Irreversible vs. reversible	8. Accidental or planned
3. Reparable or irreparable by management	9. Primary, secondary, tertiary effects
4. Duration and frequency	10. Temporary or continuous
5. Magnitude	11. Single or cumulative
6. Project based or operational	

This list is an excellent starting point for considering many different aspects of a project, and helping to ensure that no large considerations are missed. Even the Canadian Environmental Assessment Research Council's 1988, '*Checklist for Review of Environmental Assessment Process Effectiveness*' lists only three major considerations for significance, which will be discussed below.

Not all of Noble's (2006) significance elements are relevant to the discussion of air quality EAs. A brief discussion of each of the 11 criteria of significance focuses on their appropriateness for assessing air quality prediction. From the list given in Table 1, three are not relevant to the discussion of air quality impact prediction, and eight are. Why those three are not relevant is discussed first, followed by the importance of the remaining eight.

As only the air impact prediction methods are being considered, any exhaust from an incinerator will be deemed detrimental and not beneficial. Only when looking at the project as a whole could some discussion be made regarding whether it is beneficial. For this discussion, air quality impact methodology pertains only to the air impacts that occur during the operation of the incinerator, and not to any short-term air quality impacts made during the construction phase of the project, and therefore criterion number six, project based or operational significance, is beyond the scope of this thesis. Another criterion that will not be included is the consideration of temporary or continuous effects. This is because any atmospheric environmental impacts will be dominated by the continuous impacts. Therefore, the impacts will be assumed to be continuous, though they will vary in magnitude during operations because some of the projects shut down one of their stacks at a time for maintenance.

The following discussion outlines the importance of the remaining eight elements put forth by Noble (2006). His first concern is a consideration of irreversibility and reversibility as a criterion for significance. The issue of reversibility and irreversibility depends largely on context. If considered environmentally, the chemicals may not be considered irreversible because the environment is a dynamic system and these chemicals may undergo countless chemical reactions changing their form. However, the impacts may be considered irreversible in light of human health. In sufficient quantities, exposure to some chemicals emitted by an incinerator could cause irreversible adverse health conditions such as cancer, if the exposure is substantial. It is important that the manner in which any chemicals are discussed in terms of (ir)reversibility be considered if it is based on environmental fate, human health or both.

Whether the impacts from an incinerator are reparable by management practices must be considered. As was stated previously, all incinerators use pollution control measures to limit the amount of pollution being emitted into the environment. It is important to examine whether each EA discussed and determined the application of technologies to reduce irreparable damage to the environment.

In terms of incinerators, duration and frequency are not as variable as some of the other aspects of significance discussed previously as it can generally be assumed that the duration will be in the order of decades and the frequency of impact is continuous. These are important since some projects may produce impacts shorter in duration than others. The duration can be assumed to be decades long because it is simply not economically viable to create a short-term incinerator.

Magnitude will also be included in the set of significance criteria. The inclusion of magnitude must also make note of the issue of magnitude versus importance. It must be shown that the magnitude of impacts, and their significance are distinctively different (Elkin and Smith 1988). Just because an impact has a large magnitude, does not imply that it is important, and vice versa. Harrop and Nixon (1999) make the argument that impact significance is in no way the same as impact magnitude, which can be determined by observation or experiment. In terms of atmospheric environmental impacts from incineration, there are different ways in which magnitude can be discussed. Magnitude must at least include a description of the emission quantities that would be released per/hour, and any cyclical or progressive changes that may occur. These questions should be applied with reference to each chemical of concern because in each chemical behaves differently when released. Each is involved in different chemical reactions, and has different impacts on the health of humans and the environment. To ensure an incinerator undertaking is 'safe' will require the comprehensive analysis of each chemical separately and collectively.

Noble (2006) also identified geographical extent as a concern. Usually this information is given as maps that illustrate the expected range of the pollutant plume, as well as highlighting any sensitive receptors within that boundary. A determination of the geographical extent should be based on, in part, the analysis of wind rose data, which will ensure that different weather patterns will be considered regarding this extent. Seasonal or other changes must also be noted for completeness of the geographical extent criterion. Furthermore, each pollutant may have a unique profile and; therefore, affect a different spatial extent. Each also interacts with other specific air pollutants in particular ways, and has its own level of toxicity with associated health and environmental impacts. A complete discussion of geographic extent should include these as well as identifying any key receptor sites and noting populations likely to be affected by pollution.

Given the toxic nature of some pollutants being emitted by incinerators, it is imperative that malfunctions and accidents be considered. There must be plans of action, training programs, and technological back-up for these situations. Furthermore, some consideration should be given as to what the likely impacts are to be of these extreme, albeit unlikely events. Consideration of malfunctions and accidents is a particularly obvious consideration for the practice of incineration.

Addressing more than primary impacts can become an expansive task. In terms of incineration, the atmospheric chemistry of chemicals emitted from an incinerator is a complex process. Any effect on the environment caused directly is a primary impact (Shopley and Fuggel 1984). Secondary impacts are those resulting only indirectly from a project. Some chemicals, such as dioxins/furans, are pollutants to human and environmental health directly. Other chemicals are precursors to more detrimental contaminants. For example, NOx and SOx are precursors to ozone/smog and acid rain. To consider all potentially adverse impacts to humans and the environment of an incinerator's emissions, it is imperative to address not only primary impacts, but secondary and tertiary ones as well. Not all chemicals are as reactive as others, but evidence that the necessary chemicals are considered in this manner is necessary to thoroughly predict impacts.

There exists a large body of work that emphasizes the importance of considering cumulative impacts for projects assessment. Canter (1996) has cited the Canadian Environmental Assessment Research Council (CEARC) in 1988, as defining cumulative effects as effects that occur on the environment frequently in time or densely in space such that the impact is not able to assimilate. The Federal jurisdiction stipulates the inclusion of cumulative assessments within an environmental assessment of a project that will likely result in combination with other projects, is stated explicitly in the act (Canter 1996).

While it is not mandated that cumulative effects be considered in any of the relevant provincial legislation, it is considered good practice that cumulative effects will be included in the criteria for assessing the selected environmental assessments. The environmental assessments that include consideration of cumulative effects are analyzed for the inclusion of both spatial and temporal considerations. However, Duinker and Greig (2006) report a general failure to assess cumulative effects at the project level, and question whether a project EA is the appropriate level for cumulative impact assessment at all.

What will be examined during the analysis of the EAs is whether each relevant aspect of significance (as determined in this section) was used in the assessment of significance. All seven forms of significance (reversibility; reparability; magnitude; geographic extent; malfunctions and accidents; primary, secondary and tertiary impacts, and cumulative impacts) should be assessed explicitly.

2.2.4. Management and Mitigation

If during the impact evaluation stage of an environmental assessment process, it is determined that some of the impacts are 'significant,' the usual course of action is to manage or mitigate those impacts such that the impact is no longer considered 'significant'. According to Noble (2006) there are four main strategies to address potentially negative impacts, including:

- Avoidance;
- Mitigation;
- Rectification;
- Compensation.

There is no way for an incinerator to 'avoid' impacts, as that is the nature of the undertaking; likewise 'rectification' is infeasible. Compensation is not a preferred method; thus, in the case of environmental assessments pertaining to incineration, the main way that predicted impacts are managed is mitigation. Wood (1999) notes that the responsible authority's guide to the act is brief in its discussion of mitigating measures, but does emphasize that they are best addressed during the design phase of a project, and then refined throughout the environmental assessment process (Wood 1999).

Mitigation measures are specific to the type of project, and are industry-oriented (Marriott 1997), but there are still some general considerations that can be applied to the choice of measures. To address managing and mitigating impacts, there are several considerations outlined by Elkin and Smith (1988) to consider in the assessment of EAs in general. Many different considerations are presented in his description of questions; however, only some of them are relevant to the issue of air quality impacts from incinerators. These include such considerations as: Could ongoing management procedures be instituted to reduce damage? Could project design, timing, and equipment used to site management be modified to reduce effects? Could effects be monitored, and provision made for future mitigation when the exact nature and extent of effects are known better? There are always going to be many different ways of approaching mitigation measures. There will be alternatives to choose from, therefore, it is necessary that the EA explicitly document a "rationale for selection of chosen mitigating measures." (Elkin and Smith 1988). Elkin and Smith do not describe what should be included in that rationale, but some discussion of any benefits and detriments as well as options for mitigation measures is a minimum.

Elkin and Smith's comments related to mitigation in general; they dealt with specific mitigation measures. Elsom (1995) notes some specific ways that the pollution impact from an industrial stack can be mitigated. In general, impacts can be reduced by encouraging greater atmospheric dispersion and dilution of emissions by:

1. Raising stack height;

2. Reheating the flue gases to higher temperatures;

3. Emitting them at greater velocity (Elsom, 1995).

Furthermore, Elsom (1995) suggests that if exceedences are only likely during certain rare atmospheric conditions, a simple solution would be to use cleaner fuel when that particular condition is forecast. While this is not specific to incineration, it does show that there are innovative possibilities to ensure that pollution concentrations for chemicals of concern do not exceed safe levels. Any mitigation measures must be adequately tailored to the situation to be effective.

For any given problem there are various mitigation measures that may be suggested. The final choice will be based on how effective the mitigation measure is deemed to be, and how much it may cost. Mitigation is ideally implemented into the design of the undertaking which allows the different possible measures to decrease impacts to be incorporated as alternatives in the environmental assessment project description (Elsom 1995). It is standard practice for some mitigation measures to be incorporated into the

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design of an incinerator (the use of activated carbon for example), but it may be found that even with their inclusion emissions may exceed allowable levels, at which point it is necessary to determine whether the chosen mitigation measures were not enough, or further mitigation measures must be applied.

What will be examined during the analysis of the EAs is a report of mitigation measures, and their intended outcomes. Mitigation measures should have been incorporated early on in the design phase, but they should also be considered for addition later if the project should turn out to be more polluting than originally expected.

2.2.5. Monitoring

While the act of monitoring is not something that takes place during the project's proposal, and thus will not be dwelt on as extensively as the other sections, it is stipulated under the federal legislation in Canada. 'Follow-up program' is defined in section 2 of the *Canadian Environmental Assessment Act* as being a program for:

- verifying the accuracy of the environmental assessment of a project;
- determining the effectiveness of any measures taken to mitigate the adverse environmental effects of the project.

However, there is neither a means of ensuring the monitoring is implemented (Wood 1999), nor how its values are used.

Monitoring is closely tied with the concepts of sound environmental management and mitigation. Morgan (1998) outlines a number of good general reasons for its practice. Other authors have also noted benefits and uses of monitoring; however, Morgan's advice is adopted here as he presents a comprehensive list. There are a number of reasons for conducting monitoring within EA (Morgan 1998):

- To provide an early warning of unpredicted impacts;
- To check that mitigation measures have been implemented properly (compliance monitoring);
- To check that mitigation measures are effective; again, this is used for impact management;
- To provide evidence to support or to refute claims for compensation over impacts on people or property;
- To warn when target variables are reaching predetermined critical levels;
- To provide information to reassure local people;
- To reassure all participants in the EIA process, in the face of uncertainty over the impact predictions and associated management decisions;
- To examine distributional aspects: how different sectors of the community are being affected in reality;

- To audit the impact prediction processes by assessing the accuracy of the predictions, and evaluating the performance of the prediction methods and techniques;

- To document the actual impacts of an activity, for use in similar situations elsewhere.

For the purposes of air quality analysis, monitoring can be seen as compliance to ensure that emissions do not exceed acceptable levels, and contaminant concentrations in the surrounding area do not reach levels either in the short- or long-term that could be detrimental to human health or the environment. Having a publicly accessible monitoring program is a good idea for incinerators as it can help with public relations for the surrounding residents.

What will be examined during the analysis of the EAs is the inclusion of a monitoring program that lists the methods and frequency of sampling, and the number of chemicals that will be a part of the program. It is expected that the monitoring program will be designed to safeguard environmental and human health for the affected area.

Table 2. Summary of Criteria

Criteria	Evaluation
1. Impact Identification	State the problem, define the question to be answered, identify inputs, and define the boundaries (spatial/temporal) Baseline study: conducted? Where is the information acquired? Does it address all the impacts identified? Does the report describe existing conditions of key natural resources

	and land uses? Does the report describe relevant social and policy issues of a local nature relating to the project? Does the report identify variability to natural fluctuations, for example, seasonal variation in habitat use? Does the report identify variability due to human influences such as pollution from existing activities? Does the report include impact on pollution levels both current and historic? Does the report give the locations of ambient concentrations sampling sites, local pollution sources, and sensitive receptors? Does the report describe local climate and meteorological parameters? Does the report describe local topography, and physical conditions affecting pollution dispersion? Is there bias? Is there undue emphasis placed on particular stages of a project? Are the correct issues identified?
2. Impact Prediction and Measurement	Does the EA explicitly discuss the following? What is the basis for prediction: expert or simulation? To what extent is prediction based on experience with other, similar projects. If similar, details must be provided to prove similarity Does the EA describe, and provide justification, for all methods and techniques used? Does the report adequately describe relevant social and policy issues of a local nature relating to the project? Does the report identify variability to natural fluctuations, for example, seasonal variation in habitat use? Does the report identify variability due to human influences such as pollution from existing activities? What model was used, with reference to its data requirements and predictive limitations (e.g. stack height, internal diameter of stack, flue-

	gas temperature, flue-gas exit velocity) Is there both current and historic meteorological data? Are stability, temperature, mixing depth, wind speed, wind direction, humidity, precipitation, pressure, and topography explicitly discussed? How was this data obtained, and what data and parameter uncertainty was associated with it Does the report adequately describe existing conditions of key natural resources and land uses? Does the report adequately describe relevant social and policy issues of a local nature relating to the project? Does the report identify variability to natural fluctuations, for example, seasonal variation in habitat use? Does the report identify variability due to human influences such as pollution from existing activities? Were predictions substantive? Uncertainty considered for: data/parameter, model/structural, and stochastic
3. Impact Description and Evaluation	Are all the relevant aspects of 'significance' identified and considered?
4. Management and Mitigation	What techniques are used with reference to targeted problem What aspects have/have not been chosen for management Could ongoing management procedures be instituted to reduce damage? Could project design, timing, equipment used to site management be modified to reduce effects?
5. Monitoring	Does the monitoring plan include all of the following? Are stack emissions addressed? Is ambient air quality addressed? Is downwind air quality (with reference to wind rose diagram)

	addressed? Are sensitive receptors addressed? Are specific chemicals addressed with associated techniques/methods and justification those techniques/methods? What is the frequency of sampling? What is the geographic extent considered?

3. Methodology

3.1. Introduction

To analyze the hypotheses previously stated, the methodology was to extensively study the literature to find criteria for analysis of atmospheric prediction in Environmental Assessments. The previous section, Context, described that literature in detail including what sub-criteria were found, and provides examples of what will be looked for during analysis. The broad sub-criteria are: impact identification; impact prediction and measurement; impact description and evaluation; management and mitigation; and monitoring.

Six criteria have been identified based on the academic literature reviewed. It is expected that this qualitative analysis will reveal the strengths and weaknesses of the predicted impacts in each EA. Determination of where the weaknesses lie will be the deciding factor as to whether the EAs are sufficient to enable sound, environmentally precautionary decision-making.

The following sub-sections outline why a case selection analysis was used, and how the cases were selected.

3.2. EA Case Selection

In order to test this thesis's hypotheses, the number of EAs in this thesis is narrowly scoped to allow for a more detailed assessment of the predictive processes. One such way the scope is limited is by examining only Canadian EAs. The EAs assessed are comprehensive EAs only, to ensure that there are adequate data provided for each study, and if appropriate, comparison. All EAs are for incineration projects, and therefore air pollution impacts are characterized by point source emissions of pollutants.

These basic criteria were applied to a search of Canadian EAs, and three acceptable EAs were found. While a study of a larger number of EAs fulfilling the determined criteria would undoubtedly have allowed for greater extrapolation of trends, further search would likely have been fruitless. The reason is that there are few Canadian waste incinerators to begin with, and of that number, some were not required to conduct EAs, while others that were did not make the documents readily accessible.

Three EAs were found that met the criteria for selection: the environmental assessment of the Greater Vancouver Sewerage and Drainage District, of the region of the Greater Vancouver Regional District located in Burnaby, B.C.; the Remediation of Sydney Tar Ponds and Coke Ovens Sites located in Sydney, N.S., and the Residual Waste Planning Study located in the region of Durham and York, On. These three studies are not ideally suited to comparison, and have some key differences. The four main dissimilarities can be characterized by:

- Jurisdiction;
- When the EA was conducted;
- Type of incinerator;
- Type of document.

No two documents selected were a part of the same environmental assessment jurisdiction. The Burnaby EA and Durham/York document triggered the British Columbia and Ontario environmental assessment acts respectively. The Sydney EA was the result of a harmonization agreement between the provincial and federal EA legislation. Harmonization occurs when a project triggers more than one EA jurisdiction. Instead of having the proponent conduct an EA for each jurisdiction triggered, the different jurisdictions work together to create a terms of reference that they are all satisfied with, and the proponent completes only one EA for the project.

No two documents were created in the same time period. Notably, the Burnaby EA was completed in the mid-80s, while the other two were both created in the early 2000s. The time when the studies were conducted likely influenced the scientific approach used, the type of Gaussian model applied, or the manner in which the EA process as a whole was conducted.

Of the three projects, only two have similar incineration feeds. The Burnaby and Durham/York projects are based on municipal solid waste incinerators, whereas the Sydney incinerator feed is contaminated soil. The Sydney incinerator was built solely to aid in the soil remediation of the Sydney Tar Ponds and Coke Ovens site.

Of the three projects, only two are full, complete EAs. The Burnaby case study is based on the appendices for the EA, which is where all of the detailed information regarding air quality prediction is found. The Sydney EA is a complete EA, and the case study is also based on the appendices. The Durham/York case study; however, is a concept EA. A concept EA is where a proponent outlines the basics of the project without such details as site selection or perhaps the exact design of the undertaking. For the Durham and York project, this means that the general process of how the air quality prediction is going to proceed is laid out; however, the precise location, or type of incinerator is yet to be decided. Therefore, the EA is not complete, and the approach to the problem is more theoretical than the other two. The work presented for the Durham/York study is the preliminary work done for the EA process. A more detailed discussion of the incineration project for each case study is provided in the following section. The dissimilarities to be found in the three cases are not all detriments to this study – they demonstrate the variations in what is accepted in an EA.

The methodology was therefore one of appraising each of the cases in terms of the criteria adopted from the literature, to the point that the hypothesized relationships could be assessed. Tabulation of the strengths and shortcomings of the reports enabled qualitative evaluation and development of conclusions regarding the nature of EAs. There are presented following an appraisal of each of the EAs individually.

4. Case Studies

This section provides a short introduction to each of the cases selected for analysis. A much more detailed description of the cases is given in the Observations section. This section serves to provide the basic information pertaining to the types of incinerators, their locations and surrounding areas.

4.1. Burnaby Incinerator

In 1985/86 a number of air quality studies were completed and used for the Environmental Assessment (EA) of the Greater Vancouver Sewerage and Drainage District, of the region of the Greater Vancouver Regional District (GVRD), refuse incineration facility located at the Belkin Packaging site in Burnaby (Greater Vancouver Regional District 1986b). This process was started when the Greater Vancouver Sewerage and Drainage District awarded a contract to GKN Birwelco, in May of 1985, for the supply, installation, and operation of a municipal solid waste incinerator (Greater Vancouver Regional District 1986b). The incinerator, at the time of initial operation, was intended to be capable of incinerating approximately 25% of the municipal solid waste (MSW) generated in the GVRD (Greater Vancouver Regional District 1986a). The incinerator site was proposed in an area that was already densely populated in all directions for approximately 2 km (Greater Vancouver Regional District 1986a).

There are two study reports used in the general EA report that outline in detail the air quality studies considered in the approval of this incinerator. The first is titled "Assessment and Recommendations on Emission and Monitoring Requirements for Greater Vancouver Regional District Incinerator Located in Burnaby" (Greater

Vancouver Regional District 1986a) written by the GVRD in July 1986. The second report is titled "Supplementary to the Report on Emission and Monitoring Requirements for Greater Vancouver Regional District Incinerator Located in Burnaby: Public Health Considerations; Soils and Vegetation Considerations; and Mathematical Modeling Data" (Greater Vancouver Regional District 1986b) by the Corporation of the District of Burnaby in July 1986.

Both study reports provided data and predictions for the atmospheric impacts of the incinerator. Both of these reports have taken the conceptual approach of providing an assessment of the impact on air quality due to incinerator operation under worst-case emission and meteorological conditions. The differences among them are in their scope and focus, as well as the information provided. Used together they provide a comprehensive view of the air quality impacts and effects to the GVRD from the incinerator emissions.

4.2. Sydney Incinerator

In May of 2004 the Minister of Public Works and Government Services Canada and the Premier of Nova Scotia signed a Memorandum of Agreement to jointly remediate the Tar Ponds and Coke Oven sites, in Sydney, Nova Scotia. The proponents of this project were Environment Canada and the Sydney Tar Ponds Agency (STPA). They developed a proposed remediation plan (Sydney Tar Ponds Agency 2005), which consisted of several components:

- Control of surface and groundwater;

- Removal and destruction of selected contaminants from both sites (the incineration component);
- Treatment in place of selected contaminants at both sites;
- Containment of the remaining contaminants at both sites;
- Site surface restoration and landscaping at both sites;
- Development of long-term monitoring and maintenance plans at the site of the incinerator.

The undertaking is located in the Cape Breton Regional Municipality (CBRM), Nova Scotia. It entails three principal sites: the Tar Ponds site; the Coke Ovens site; and a location for a temporary incinerator. The Tar Ponds and the Coke Ovens sites are located near Sydney harbour and the centre of Sydney. The temporary incinerator was proposed for a location approximately 5 km North of the Tar Ponds and the Coke Oven sites, on an abandoned industrial site (the former Victoria Junction Coal preparation plant, referred to as the VJ site).

Unlike the other two projects selected, this project was not created to address a need for municipal solid waste disposal. Instead, this project was built to address the fact that Sydney has been subject to 100 years of coal and steel production that has substantially contaminated the surrounding environment (Sydney Tar Ponds Agency 2005). From the industrial activities of the last one hundred years, the most contaminated area comprises about 100 ha in the Sydney downtown core (Sydney Tar Ponds Agency 2005). The area is surrounded by residential, commercial and industrial land uses. The EA document stated that the contamination at the sites had created increased risks to human health and the environment, and therefore, there was a need to treat the soil by incineration.

The EA document (Sydney Tar Ponds Agency 2005) stated that the materials to be incinerated included 120,000 tonnes (92,000 m^3) of sediment containing (among others) polychlorinated byphenyls (PCBs) materials from the Tar Ponds and 26,000 tonnes (13,500 m^3) of polycyclic aromatic hydrocarbon (PAH)-contaminated sediments from the Coke Ovens site (Sydney Tar Ponds Agency 2005). Specifically, the hazardous substances principally included PAHs, other organic contaminants such as heterocyclic aromatic hydrocarbons and polychlorinated hydrocarbons PCBs, ammonia, sulfur, metals (Cd, Hg, Pb, and Zn), and benzo[a]pyrene.

4.3. Durham and York

In 2005 the Durham and York Regions in Ontario agreed to undertake a joint Residual Waste Planning Study. Both municipalities were in need of a solution to manage the remaining solid waste after diversion (residual or post-diversion waste) (Durham and York Regions 2005). Even with the expanded source-separated diversion efforts, Durham and York continue to face the challenge of managing residual waste. Both Regions face a shortage of available landfill capacity over the long term. In response to this situation, the Regions described the purpose of the undertaking (Durham and York Regions 2005):

> is to process – physically, biologically and/or thermally – the waste that remains after the application of both Regions' at-source waste diversion

programs in order to recover resources – both material and energy – and to minimize the amount of material requiring landfill disposal.

In proceeding with this undertaking only those approaches that would meet or exceed all regulatory requirements were to be considered.

The description of this EA focuses on the energy-from-waste (EFW) aspect of the waste management plan of Durham/York. The EA had not yet picked a particular site in which to house an EFW facility, thus making it a concept EA. Instead there is a detailed section in the EA that stipulates the process that will be undertaken to choose a site. However, the location of a possible thermal treatment facility was to be within the well-populated regions of Durham and York.

The following section discusses the observations found when applying the criteria to the three cases studies.

5. Observations

5.1. Introduction

This section applies the criteria outlined in Chapter 2 each of the three EA case studies. Little discussion is given, but rather only observations as to the process undertaken in the EA will be noted. Tables for each of the major sections provide easy comparison among the three EAs. However, it should be noted that the EAs are not all structured the same way and they do not always use the same terminology.

5.2. Burnaby Incinerator

5.2.1. Impact Identification

The *Impact on Air Quality Due to Solid Waste Incineration at the Belkin Site* (Greater Vancouver Regional District 1986a) report analyzes the likely concentrations of pollutants during the "worst-case" scenario of two-day calm conditions. The impact identification focused on determining which pollutants would be considered for analysis. The pollutants that are considered are: total suspended particulates (TSP); lead (Pb), cadmium (Cd), nickel (Ni), mercury (Hg), hydrochloric acid (HCl), hydrogen fluoride (HF), SOx (as SO_2), NOx (as NO_2), hydrocarbons (HC) (as CH_4); carbon monoxide (CO), and dioxins/furans. The discussion of each of these pollutants consists of no more than three sentences for each. One states the estimated worst-case 24-average concentration; another states what the regulations are; and a final concluding sentence explains quantitatively how far below the allowable limits the concentrations are expected.

Expectations were derived from a baseline study conducted to determine the pre-project air pollution levels. This study consisted of 7 different monitoring stations in the Greater Vancouver Regional District (GVRD) over the years 1982 to 1984 inclusive. The data gathered were summarized in two tables representing the percentage concentration of each of the pollutants monitored in both the 24-hr guideline and the 1-hr guideline. The 24-hr and 1-hr averaging for concentrations are the two most common averaging techniques used in Canadian regulations. There is an accompanying table that shows the concentration levels of those pollutants in the ambient air after the incinerator is expected to be in operation not including the concentrations that were determined during the baseline study based on expected pollutant releases. What this study omitted was specific reference to the existence of any other major polluters in the vicinity.

The baseline description of the vicinity also includes mention of local topography, population, and meteorological conditions. The topography data are limited to a 6 km distance north of the incinerator, showing a rise in elevation in this direction. However, there were no other topographical data given for the site. The surface wind data, presented graphically, comprised a wind-rose diagram for 8 directions at the Vancouver International Airport for the years 1955 to 1980. While the local wind speed data are referred to as having been collected, there is no presentation of these data. The meteorological data, and pollutant concentration data are not discussed in terms of expected changes in values during natural or seasonal fluctuations.

For each pollutant the EA document provides a common formula for how the data on that chemical are presented. It starts with a discussion of why that chemical is a pollutant, and how it is commonly formed in the incineration process. There is then a brief discussion of the various factors in the incineration that can affect the production of the chemical(s), followed by the management tool chosen to address that particular pollutant. All of the chemicals, except for CO and HC (hydrocarbons) follow this method. For CO and HC there is no explanation of which combustion parameters affect their production, and the EA does not identify specific emission control devices. The document states that "these parameters can be adequately controlled through proper design and operation of the furnace….the….system is capable of maintaining high combustion efficiencies, thus minimizing CO and HC production."

Trace metals are not discussed individually but as a group. The EA document states that only chemicals with suspected health effects were considered. The particular trace metals referred to are not listed, rather the reader must refer to a table located further on in the document to determine which trace metals are included in this list, and considered to be "producing known or suspected health effects."

For trace organics, it is admitted that there was limited knowledge on the subject: "the relative lack of knowledge of the health impacts of many organic compounds detectable in incinerator exhaust gases makes an assessment of health effects quite difficult." The focus is on dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) because of their "toxic nature."

The EA document ends the discussion of pollutants by stating that:

> the list of emission parameters considered in this report is by no means exhaustive, but includes those of most concern. Other materials such as asbestos and cyanide are not considered to be present in concentrations high enough to warrant specific emissions control measures.

There is no explanation of how it was determined that the list includes all of "those of most concern," be it in reference to human health or environmental impacts. The baseline data are also presented graphically for the chemicals of concern.

Table 3. Summary of Impact Identification for the Burnaby Incinerator

Criteria	
1. Impact Identification	**Positive Attributes** Provides list of substances and states why they are potentially harmful (to human health). Admits to limited knowledge of the impact to human health from trace metals. Includes baseline study with reference to: substances listed as harmful, wind speed and direction, population, local topography, and meteorology. **Negative Attributes** Local topography description is limited to elevation for 6 km surrounding proposed site of undertaking. Population data does not go into detail regarding: area, distribution, composition or density. No climate data are given. No land use data are given. The EA does not reference existence or absence of any other major polluters in the vicinity. Wind speed data are mentioned as existing but not presented .

5.2.2. Prediction

The *Impact on Air Quality Due to Solid Waste Incineration at the Belkin Site* (Greater Vancouver Regional District 1986b) document uses two different Gaussian models to determine the impact on air quality due to incineration emissions. Estimates of potential maximum ground level concentrations of the various pollutants under 'worst-case' meteorological conditions were calculated. Each model was selected and applied to estimate concentrations at ground level from incinerator operations during meteorological conditions conducive to the highest pollution potential. Both Gaussian models were used to predict 'worst-case' scenarios, but it is not mentioned how 'worst-case' was defined.

The specific objectives of this study were to:

- Define the quantity and chemical composition of air emissions from the incinerator based on the design specifications;
- Estimate resulting ground level concentrations of various pollutants during worst-case plant emission and meteorological conditions;
- Provide an assessment of impact on existing air quality due to incinerator air emissions;
- Summarize the findings and conclusions of this study in a formal report.

To address the first aspect, the specifications for the plant emissions were explicitly based on the maximum allowable levels stipulated in GVRD's design contract. In the second part, the emissions were based on published data for similar installations in North

America and Europe. The document does not give specific information about the type of incinerators selected to provide the estimates.

A specifically designed "box model" was used to predict ground level concentrations during prolonged calm conditions. The second model, STACKS, was applied to estimate the dispersion of pollutants during conditions associated with wind. Both models account for the effects of topography and assume that dispersion takes place in a mixed layer below an elevated inversion thereby also representing worst-case meteorological conditions.

The box model was chosen to model calm conditions because it is capable of predicting the influx of pollutants into a gradually expanding space up to a maximum size dictated by the maximum travel of pollutants due to light and variable winds. Calm conditions are characterized by light winds of less than 2 km/hr, particularly in the presence of an inversion. Inversions can aid in the accumulation of pollutants by keeping pollutants trapped below the inversion level. In this situation, ground level concentrations could attain values much larger than those associated with moderate to strong wind. These conditions are used to model the "worst-case" scenario involving the greatest likely ground-level concentrations of pollutants emitted from the incinerator. The "worst-case" scenario results are based on a conservative estimate after two consecutive days of calm (Greater Vancouver Regional District 1986b). These prevailing light winds are due to the influence of land/sea breeze and upslope/downslope wind. The lateral dimensions of the box, and the relative location of the stack within the box were calculated from wind data measured at the Vancouver airport. The total volume of the box was estimated to be 29.1 km^3. This volume is based on an estimated maximum plume height of 246 m.

The Supplementary to the report on Emission and Monitoring Requirements report explicitly details the two main assumptions that were made concerning this model (Greater Vancouver Regional District 1986b). One was that pollutants were assumed to be uniformly distributed in a mixed layer below an elevated inversion with a base at the height of the maximum plume rise. The other was that the lateral dimensions of the box were calculated assuming an average mean wind speed of 1 km/hr with directional wind frequencies characteristic of low wind speeds.

The main document directs the reader to Appendix B for a more in-depth discussion of the model being used. Appendix B describes the methods as the "well known 'Box Model' approach." Appendix B does give an equation for buoyancy rise and is related to the prediction equation where maximum plume height was assumed to be the sum of physical stack height, buoyancy rise and momentum rise.

There is also a table which outlines where in the box model the incinerator is located. This is based on the assumption that the average daily wind speed is 1 km/hr. This table also gives the relative frequency of light wind percentage by direction, and the distance travelled by pollutants. The Appendix also presents a figure to visualize the method used to calculate the pollutants during calm conditions. This is done to depict the various results depending on the estimation of a one-hour peak concentration or daily average with sequential days associated with calm winds.

Unlike the model for worst-case pollution concentrations during conditions of wind, the appendix for calm conditions does give some discussion of the assumptions inherent in the model. It is based on a "reasonably realistic sequence of events:"

- Between 0 and 12 hours from the onset of calm conditions, pollutants were assumed to be uniformly distributed in the vertical, but only in a space corresponding to one quarter of total box volume;

- Between 12 and 48 hours, the volume of space occupied by pollutants will gradually increase as a linear function of time until the maximum volume of the box is attained at the end of 48 hours;

- After 48 hours the pollutants remain uniformly distributed in a fixed space equal to the total volume of the "box."

Dispersion of pollutants during "worst-case" meteorological conditions associated with wind were predicted for 1-hr maximum level concentrations using the STACKS model developed by the Alberta Department of the Environment. The model considers dispersion of pollutants in a mixed layer below an elevated inversion at the height of the plume, or 100 m, whichever is greater. The model was applied separately for 8 compass directions. In each case, ambient air concentrations at ground level were calculated for as many as 20 downwind locations and 12 different wind speeds varying from 3.6 km/hr to 72 km/hr. Modelled receptor points were selected at 500 m increments up to 10,000 m from the stack. The maximum predicted overall ground level concentration was extracted and compared with regulatory guidelines for ambient air quality.

The main text of the document directs the reader to Appendix A should he or she be further interested in this model. Appendix A further directs the reader to a detailed description of the model and the inherent assumptions located in a report published by Alberta Environment. Therefore, there is no outright discussion of the assumptions of the model, or the possible accuracy of using the model for this particular study. The Appendix does present some data about the results of the application of the model to the study in a graphical form not seen in the main document itself. First there is a table entitled "maximum ground level concentration factors" which gives a list of receptors and the concentrations at each associated with particular wind speeds, and notes which direction receptors are found in relation to the plant and how far they are from it. No data are provided to explain how or why those receptors were chosen, nor a map for easier understanding of their location surrounding the incinerator.

The models used the following data to describe the characteristics of the incinerator and technology used to determine the impact on local air quality. The MSW incinerator is proposed to consist of three separate process units each with a capacity of 9,500 kg/hr. Therefore, the maximum daily capacity of the system will be 684,000 kg of waste burnt, and the total annual throughput will be 210,000,000 kg.

Table 4. Physical Specifications of the Burnaby Incinerator

Stack height = 60 m	Exit Diameter = 1.35 m
Exit Velocity = 15.2 m/s	Exit Temperature = 130 °C
Volume of Flow = 21.7 m^3/s	Temperature in Incinerator = 980 °C
Incinerator Residence Time = 1.5 s	Processing rate = 9,500 kg/hr

Going back to the model, very few substantive predictions were given for either model. Rather, the predictions show that the emissions result in ground level concentrations that are "well within ambient regulatory guidelines." Only for TSP and NO_2 were numbers used at all. It was predicted that the "maximum contributions to total suspended particulate (TSP) due to the incinerator are only 7 percent of measured existing maximum TSP levels." The report also states, "contributions of NO_2 are shown to be only 60 percent of those measured, however, this is a conservative estimate." Despite the lack of substantive data, the most likely negatively impacted surrounding areas were identified. The conclusion for estimated "maximum contribution to ambient air pollutant levels (24-hour and 1-hour periods) due to incinerator operation under worst-case plant emission and meteorological conditions" is presented in the EA. This aims to show that in the immediate vicinity of the incinerator, none of the studied pollutants will exceed guidelines. It is not clear from the figure and the text, how this graph was created, and what data had been used for it.

Table 5. Summary of Impact Prediction for the Burnaby Incinerator

Criteria	
2. Impact Prediction and Measurement	**Positive Attributes** Gives specific objectives of the study States how emissions estimates are made Defines 'worst-case' scenario for conditions with and without wind States some assumptions for Box model **Negative Attributes** Emissions estimates are based on maximum allowed – no discussion on plausibility or possible variability For 'Box model' does not present likelihood of events For model under conditions of wind: no assumptions are given Not clear how receptors were chosen for either model Results from either model are not presented, such that it is not possible to compare results with stipulated local regulations Graphics are not clear

5.2.3. Impact Description and Evaluation

The assessment as to whether the incinerator pollutes unacceptably in terms of air quality was determined by comparing the estimated concentrations with the regulatory guidelines for ambient air quality. Cumulative effects were also considered by comparing the pollution estimates from the incinerator with the data gathered from the Pollution Control Division of the GVRD for the existing levels of air quality. The chemicals considered for evaluation were: TSP, lead, cadmium, nickel, mercury, HCl, HF, SOx, NOx, HC, CO, and dioxin/furan.

The conclusion, as noted in the prediction section, was that "in general" the results for all pollutant estimates under differing weather conditions were shown to be "well within" regulatory limits. The conclusion further emphasized the different ways in which the estimation was conservative.

The concepts noted in the methodology section pertaining to 'significance' were not considered in any depth. Duration and frequency was touched on for the prediction section as the prediction assumed that all three stacks would constantly be in use, which is a conservative estimate as each will have to undergo maintenance, though no substantive estimation was given for the difference in effect between the two predicted emission levels. Magnitude was considered obliquely. A comparison of the predicted values against the safety guidelines for each contaminant, can be considered an indicator of magnitude. However, the reader is not privy to the actual values found for each of the chemicals for either model or worst-case scenario. Geographical extent was determined in the box-model; however, geographical extent in the STACKS model was not so specific, and tended to use broad terms for the GVRD. Accidents and malfunctions were mentioned in the document, but only to mention the protocols set up in the plant. There was no estimation of the possible effects of such an accident or malfunction. Only primary impacts were directly estimated. While it was implied that secondary and tertiary effects are important in the area, given ozone is a problem in the GVRD, only NOx was measured, and there was no attempt made to determine how this level of NOx would impact the ozone in the GVRD, nor an attempt to determine what proportions and types of NOx species would be present. Cumulative effects were considered in passing, but no values for the temporal or spatial accumulation of pollutants were given. As such, it is unclear whether human health, environmental impacts or both were fully considered.

No uncertainty analysis was completed for any of the 3 mathematical models used in this study. However, for the model used in determining the placement of monitoring locations, some discussion of the factors that may affect the model's accuracy was given.

Table 6. Summary of Impact Description for the Burnaby Incinerator

Criteria	
3. Impact Description and Evaluation	**Positive Attributes** The EA addresses cumulative, duration and frequency, magnitude, primary/secondary/tertiary impacts, geographic extent, and accidents and malfunctions. The EA states that unacceptability is based on comparison with regulations. The model used to aid in the selection of monitoring sites discusses what may effect model accuracy. **Negative Attributes** While cumulative impacts are considered, the EA does not go into detail as to how this was accomplished. The estimates for the pollutants considered were "in general … well within [the] limit" but does these are not explained quantitatively. Geographic extent is only described in terms of the 'box model' and not the Gaussian model. Accidents and malfunctions are described only in terms of general protocols, and no estimation is given for possible likelihood of identified potential accidents or malfunctions. Primary/secondary/tertiary impacts are only implied with reference to potential for negatively impacting the ozone conditions in the GVRD, but no analysis quantitative or qualitative of the likelihood is given.

5.2.4. Management and Mitigation

Managing and mitigation measures are described in several parts of the document. They are noted in describing the general characteristics of the incinerator, and as well as identifying the chemicals of concern. As with the incinerator itself, there is neither mention of alternative technology, nor how the selected methods were chosen. There is also no substantive data provided as to how well they work, and what affects their performance. As the results for the prediction were satisfactory, there was no iterative step that considered the addition of further management and mitigative measures to abate the negative effects of emissions. There was, however, the note that should the monitoring conducted during the operation of the incinerator show that it is exceeding limits, measures would be taken to rectify the exceedences. Those 'measures' were not explained.

Table 7. Summary of Management/Mitigation for the Burnaby Incinerator

Criteria	
4. Management and Mitigation	**Positive Attributes** The EA recommends monitoring. **Negative Attributes** There is no mention of alternatives or how selected methods were chosen. There are no substantive data on how well models work, or what affects their performance. There is no discussion of how mitigation and management will be used in light of prediction data.

5.2.5. Monitoring

The model COMPLEX II, was used to aid in ambient air quality monitoring station site selection. No particular pollutant characteristics were modelled during this stage. COMPLEX II was obtained from the US Environmental Protection Agency (EPA) UNAMAP series. This model was used to make "recommendations for the sites where monitoring should take place" (Greater Vancouver Regional District 1986a). The report states that this model can handle a large number of emission sources at different locations, while making adjustments for topography. It uses a year of hourly surface weather observations and a year of maximum and minimum mixing height data. The report indicates that COMPLEX II was not the best model for the terrain of the project site. It was however, stated to be the best one readily available (Greater Vancouver Regional District 1986a). The hourly surface weather data were obtained from the Vancouver airport for 1984 and the mixing height data were obtained from Port Hardy's upper air station.

Using the model, maps were generated to show the highest concentrations over averaging times of one, three, eight and 24 hours. The results for all averaging times were similar in that they predicted the highest concentrations to occur on the south slope of Burnaby. The conclusions from analysis of the isopleths were four, very broadly defined, and recommended locations for ambient monitoring sites.

It was only in the atmospheric dispersion model COMPLEX II that impacts to model accuracy were addressed. There are four main impacts that have been identified.

There may be some significant differences in surface weather conditions between the Vancouver airport and the site of the incinerator. For example, according to the report, the wind direction at the incinerator site is likely turned 10 or 20 degrees counter-clockwise from that at the airport, due to the effects of local topography. The report stated that this would only affect long-term trends and not short-term ones.

The model's results assumed that 1984 was a representative year for data collection. Yet, the document then explained how a comparison of 1984 wind speed and stability conditions and long-term conditions at Vancouver Airport indicated the year 1984 was, in fact, atypical. The EA document purports that 1984 was atypical in a manner that increased the conservative estimates of the model as there were more frequent occurrences of conditions that were conducive to poor atmospheric dispersion of pollutants in the monitoring period.

Having used upper air meteorological data from Port Hardy rather than a location closer to the Burnaby incinerator added uncertainty. However, the report claimed that it would probably not be significant as far as the estimation of maximum impact is concerned; yet it raised the concern that incorrect inputs may result in significant errors in the estimated annual average concentrations.

The terrain adjustment factors used provided a reasonable estimate of deflection of the plume when it approaches elevated topography. If as much deflection had not been used, the estimated concentrations would have been higher. The EA document asserts that the analysis was as conservative as it could have been.

Emission rates of the various pollutants considered in this study were selected from two sources. The GVRD's contract specifications limited allowable emissions of TSP, Pb, Cd, Ni, Hg, HCl, HF and SOx as SO_2. Published data on the measurements of emissions at modern incinerators were used to estimate emission rates for NO_2, HC as CH_4, CO and dioxins and furans. This model used the same incinerator characteristics as the other two models in this EA study.

This section of the EA also outlines the ambient air quality monitoring that did take place. During the course of study, the document concludes that throughout the study, it became apparent important pieces of information were not available, including the public health monitoring for VOCs. The document also noted a lack of research done into the impact from nitrogen-substituted aromatics, and the levels of contaminants in vegetables and fruits that are safe for human consumption.

The ambient monitoring study concluded with seven air quality-related recommendations:

- A comparison of the sum of existing ambient metals/particulates and those expected to arise from the incinerator with ambient objectives, indicates that particulate arsenic, cadmium, lead and nickel are prime candidates for monitoring;
- A similar comparison with gaseous parameters revealed that CO, HF, NOx, and SO_2 could be expected to be elevated with the onset of incineration to a degree that warranted continuous monitoring as well;

- A risk assessment of organics such as PAHs, dioxins and furans revealed that the risk is apparently lower than many common activities but assurance that the levels are and will remain low at this incinerator were needed from regulators;

- Meteorological monitoring of wind speed/direction and mixing heights was recommended to verify and predict pollution episodes and provide raw data for future modeling exercises;

- Four permanent monitoring sites were recommended to be located in the study area at sites where higher contaminant levels are predicted to occur. Three are full stations and one is considered a satellite station;

- Some information was unavailable for this review and was listed for collection at some time in the future;

- A technical review committee was recommended to review the data generated by the monitoring program. The purpose of this committee would, at the onset, be to identify important trends and identify future monitoring needs.

Table 8. Summary of Monitoring for the Burnaby Incinerator

Criteria	
5. Monitoring	**Positive Attributes** The EA has a model to aid in the selection of monitoring sites. Uncertainty is addressed, and outlines aspects that may affect model outcomes, and discusses qualitatively how the may affect the model outcomes. The EA notes that the data available was insufficient for type of analysis planned, and outlines the type of data needed to improve analysis.

	The EA gave seven recommendations for monitoring. **Negative Attributes** The EA does not give specifics as to the manner in which monitoring will take place.

5.3. Sydney Incinerator

5.3.1. Impact Identification

The baseline study and impact identification were described in the main Environmental Assessment document. The baseline study for the atmospheric impact was created with an ambient air-monitoring program (AAMP) started in 2001. The program consisted of monitoring the levels of dioxins, furans, $PM_{2.5}$, PM_{10}, TSP, 30 metals, 15 PAHs, and 37 VOCs. The rationale given for the inclusion of these indicators is that "they met one or more of the following criteria:

- They are frequently present in the airshed;
- They are known to be on either the Tar Ponds or Coke Ovens site in significant quantities;
- They have been identified as "toxic" under CEPA;
- In the past there has been an issue such as an exceedence or noticeable trend, with the compound.

Local weather conditions were also gathered at this time. These were gathered from two sites: the former Public Information Display Centre, and the Coke Ovens weather station located at the southeast perimeter of the Coke Ovens site. There is a table that summarizes the data for the annual weather data for 2003 for the Tar Ponds and Coke Ovens weather station, so that a 30-year climate 'normal' could be estimated from the Sydney Airport. The section provides a breakdown summary of the findings for the following weather aspects: prevailing winds, precipitation, seasonal fluctuations, climate normals for 1971-2000, temperature, annual mean daily maximum temperature, annual mean daily minimum temperature. There is also a wind-rose diagram to graphically describe the data, with accompanying discussion of seasonal changes.

The document provides a brief history of the air quality in the region, noting specific industries over the past 100 years that have caused negative impacts to air quality. This led into a discussion of current industry in the area. The document stated the main sources of industrial emissions in the Sydney area to be: power plants, the Sydney Airport, landfills, petroleum bulk storage facilities, a municipal incinerator, quarries, and materials handling facilities.

Land use data were also given using a GIS, and maps were provided showing monitoring sites for the air quality testing.

The EA defines what is meant by significance in terms of air quality:

> A significant adverse effect on air quality is one that involves predictable, sustained or frequent (e.g. more than ten times a year for 24-hr criteria) exceedences of any applicable regulatory criterion or objective regardless of whether there is a demonstrable adverse effect to any VEC [valued ecosystem component] that relies upon the atmospheric environment.

Table 9. Summary of Impact Identification for the Sydney Incinerator

Criteria	
1.Impact Identification	**Positive Attributes** The EA had a baseline ambient air quality study undertaken 2001, and had local weather data for 2003 including: prevailing wind, precipitation, seasonal fluctuation, climate normals, temperature. The EA presented a rationale for the selection of substances for inclusion in baseline study. The EA discusses historical air quality problems with detail into the industries responsible. The EA defines 'significance.' **Negative Attributes** The EA does not consider applicability of baseline data sampling techniques, or possible errors from its use.

5.3.2. Prediction

The prediction section notes the type of data required to include emission rates, characteristics of contaminants, spatial relationships of the source and receptors, and meteorology.

The proposed incinerator will have a probable design capacity of approximately 10 tonnes/hr. The design proposed was a rotary kiln type of incinerator. The feed, consisting of solid materials, is fed into the primary combustion chamber via conveyor or auger and exposed to high temperatures of around 800 °C for a period ranging from 20-40 minutes.

Table 10. Physical Specifications of the Sydney Incinerator

Stack Height	30 m	Exit Diameter	1.08 m
Exit Velocity	25 m/s	Exit Temperature	120 ^oC
Volume of Flow	22.89 m^3/s	Temperature in Incinerator	800 ^oC
Incineration Time	20-40 min	Processing rate	10,000 kg/hr

The incinerator will be a dedicated, temporary, constructed facility to be used only to incinerate contaminated materials that are a part of or generated during this remediation project. It will operate for 24 hours a day, 7 days a week for approximately 250 days per year. The EA does not stipulate for how many years.

The proposed incinerator system will include the following components: a waste material feed preparation area; a waste feed system; combustion chambers (primary and secondary); an exhaust gas stack; a stack gas treatment area to clean stack gases (a scrubber); a stack gas particulate capture device; a treated material (ash) handling/disposal system; and energy and control systems.

Air dispersion modeling was conducted for the normal operational mode for the proposed incinerator. The predicted maximum ground-level concentrations of the criteria pollutants were determined and compared against regional standards.

The AERMOD dispersion model was used in this study. The report states that the model can be applied to rural and urban areas, flat and complex terrain, surface and elevated releases, and multiple sources (including point, area, and volume sources). AERMOD is a steady-state plume model, and it constructs vertical profiles of required meteorological variables based on measurements and extrapolations of those measurements using similarity (scaling) relationships. Deposition modeling predicts three forms of deposition: total deposition, wet deposition, and dry deposition, with total deposition the sum of wet and dry deposition.

The specific model inputs for the dispersion and deposition modeling include meteorological data, terrain considerations and the inventory of emissions. The local meteorology of the region was assessed to evaluate the short-term atmospheric dispersion and transport of emissions released by the incinerator. The data required to predict dispersion and transport of the exhaust plumes included: surface wind velocities and direction, temperature, atmospheric stability, and mixing layer depth. Wind and temperature data were readily available from nearby meteorological stations, but atmospheric stability and mixing layer depth were calculated from additional raw meteorological data which included: cloud cover, snow cover, and solar radiation.

A table was provided to show for each of the predicted averaging times, the provincial Nova Scotia maximum permissible ground level concentration regulation, and the predicted maximum ground level concentrations for human health. It was determined that the routine operation of the facility will meet "the majority" of air quality standards for the contaminants modeled. The only chemical that would not is SO_2. Mitigation measures were suggested to deal with SO_2 exceedences. The prediction for SO_2, with the inclusion of the stipulated mitigation measures, was that it would meet the regulatory requirements.

It was noted that accurately estimating emission rates is a priority, which requires considering relevant regulatory limits and design factors that will be incorporated into the construction of the incinerator. The document goes on to note that the Canadian Council of Ministers of the Environment (CCME) has set the limits for specific chemicals, and then provides a table of estimated emission rates for the incinerator, yet it does not explain how those estimates were created.

After an initial overview of the type of model AERMOD is, the pollutants to be measured were broken down into specific groups: deposition, particulates, carbon monoxide, SO_2, and NO_X. The prediction results for each of the two possible sites for the incinerator were given for the chemical categories providing a table to compare predicted ground level concentrations and the regulatory guidelines.

The model inputs included: meteorological data, terrain considerations and the inventory of emissions. A wind rose diagram was presented to represent the wind speed and direction data, also described in the text. The AERMET model was used for meteorological data processing. It is not stated how the data required for AERMET were acquired. For the terrain data, a Cartesian receptor grid was created with receptors spaced 100 m apart for the area surrounding the proposed facilities. A map was provided of the sites showing where the receptors are located for each incinerator. There is also a table showing the input parameters for each site.

Table 11. Summary of Impact Prediction for the Sydney Incinerator

Criteria	
2. Impact Prediction and Measurement	**Positive Attributes** The EA presents types of data required for model: emission rates, physical geometry of sources of contaminants, spatial relationships of sources and receptors, and meteorological elements. The EA presents meteorological data. **Negative Attributes** The EA does not justify emission rates data, uses maximum allowed concentration as basis without discussing variability or variations, and data are not supported by quantitative data. The EA does not discuss spatial relationship of sources and receptors.

5.3.3. Impact Description and Evaluation

Malfunctions and accidents are considered, and explicitly addressed in the document but only those that have a "reasonable probability" of occurring. A list is provided stating all malfunctions and accidents of reasonable probability, only two of which can impact air quality: combustion – related failures in the incineration process; and failure of the emissions control system.

The solution provided was an environmental management program (EMP). The EMP will follow prescribed regulations, will provide detailed protocols for the management of hazardous materials (e.g. emission control, safe storage practices, spill contaminant, emergency response, regulatory compliance, etc.). There are no specifics given for the EMP related to either human health or ecosystem responses.

Cumulative effects were considered as well. The EA identifies that there are several existing other nearby sources of pollution that may create air quality conditions with the possibility of interacting negatively with air quality caused by the incinerator. However, the section explains that predictions were made and the other projects were found to be sufficiently far from the project incinerator. The potential cumulative effects were assumed to be spatially independent.

This section summarizes the adverse effects on air quality as "unlikely", and stipulates that periodic monitoring will ensure that any adjustments to mitigation methods can be made.

Volume 1, Section 8 of the EA deals with malfunctions and accidents which is the closest this EA comes to uncertainty analysis. The objective of the assessment of possible environmental effects of malfunctions and accidents was to ensure that:

- Abnormal events and/or operational upset conditions are considered;
- The significance of the residual effects (i.e. after mitigation) of such events is determined;
- Probable accidents and malfunctions have been identified.

The conclusions drawn in the document were that no exceedences of any acceptable ground level concentrations are predicted once an acid control system is applied to reduce acid gas emissions during incineration operation.

After incorporating the proper design measures (e.g. scrubbers, quench towers, etc.) into the construction of the proposed incinerator it is expected that it will only produce emissions that are within the provincial guidelines.

Table 12. Summary of Impact Description for the Sydney Incinerator

Criteria	
3.Impact Description and Evaluation	**Positive Attributes** The EA lists all likely malfunctions and accidents. The EA mentions that cumulative data were considered. **Negative Attributes** The conclusion provided after analysis of prediction data are that the project will "likely produce within provincial guidelines." For listed malfunctions and accidents the solution provided is regulation and protocol - no specifics are given, nor quantitative data for the likelihood of such events occurring. Cumulative data were not presented, and only the conclusion given that sources were found to be sufficiently far away to not pose a problem. The EA lacks quantitative data and statistical analysis.

5.3.4. Management and Mitigation

SO_2 during the course of prediction was found to be over the regulatory limits. To deal with this problem acid control systems were to be required, which was stated to result in an acid gas emission reduction of at least 80%, thus allowing the SO_2 concentration to be within the allowable range.

The EA does not specify what the final mitigation measures would be, but stipulates that they "will likely be composed of a baghouse filter, scrubber, and/or cyclone."

Table 13. Summary of Management/Mitigation for the Sydney Incinerator

Criteria	Sydney
4. Management and Mitigation	**Positive Attributes** SO_2 was found to be over regulations and management measures were applied to rectify – acid control required. **Negative Attributes** No options were given for type of management, or justification for its effectiveness. The EA notes that there will be other management measures included in design but not how that choice will be made, or to solve what problem.

5.3.5. Monitoring

A long-term monitoring program was stipulated to be a part of the project development. The monitoring would follow the air sampling procedure of the National Air Pollution Schedule (every 6 days). There was no detailed monitoring program outlined in the EA, but it stated that a monitoring program is to be developed and included in the EMP.

The objectives of the monitoring program are to:

- Ensure that the operational requirements and objectives of the remediation works are met;
- Assist in verifying effects predictions of the EIS;
- Confirm effectiveness of the mitigation measures proposed in the EIS;

- Determine the need for new mitigation strategies as required to address unanticipated adverse effects and/or ineffective mitigation;
- Ensure proper implementation of the mitigation measures outlined in the EIS;
- Ensure compliance with regulatory permits, approvals, and requirements.

There is no mention of where the monitoring should take place, or what substances are intended to be monitored.

Table 14. Summary of Monitoring for the Sydney Incinerator

Criteria	
5. Monitoring	**Positive Attributes** The EA includes a long-term monitoring program with some details as to sampling procedures. The EA lists objectives of monitoring program. **Negative Attributes** There is no mention of where monitoring will take place. The majority of details for the monitoring program were left to be determined at a later date. There is no mention of what substances were to be monitored.

5.4. Durham and York Incinerator

5.4.1. Impact Identification

There are two separate sections within this study that identify substances to be predicted: the main atmospheric prediction section, and the generic risk assessment section.

The generic risk assessment section identifies a number of substances to be included in the prediction section. As no particular type of incinerator model, or manufacturer had yet been chosen, specific information on chemicals in stack emissions was not available.

There were 6 main categories of substances of potential concern: metals, chlorinated monocyclic aromatics, chlorinated polycyclic aromatics, combustion gases, polycyclic aromatic hydrocarbons, and volatile organic carbons.

Table 15. Durham and York Incinerator - Substances in Generic Study

Metals	Antimony, Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Cobalt, Lead, Mercury, Nickel, Phosphorus, Silver, Vanadium, Zinc
Chlorinated Monocyclic Aromatics	1,2-dichlorobenzene, 1,2,4-trichlorobenzene, 1,2,4,5-tetrachloro-benzene, pentachloro-benzene, hexachloro-benzene, 2,4-dichlorophenol, 2,4,6-trichlorophenol, 2,3,4,6-tetrachloro-phenol, pentachloro-phenol
Chlorinated Polycyclic Aromatics	PCBs 2,3,7,8-TCDD-(dioxin/furan) –TEQ
Combustion Gases	PM_{10}, $PM_{2.5}$, CO, HCl, NOx, SOx
Polycyclic Aromatic Hydrocarbons	Benzo(a)-pyrene, Benzo(a)-anthracene, Benzo(a)-pyrene, Benzo(b)-fluoranthene, Benzo(g,h,l)-perylene, Benzo(k)-fluoranthrene, Chrysene, Dibenzo(a,h)-anthracene, Indeno(1,2,3-cd)-pyrene, Anthracene, Naphthalene, Phenanthrene
Volatile Organic Carbons	Benzene, Chloroform, Tetrachloro-ethylene, Dichloro-methane, Formaldehyde, Vinyl chloride

This was the list of chemicals for which impacts were to be predicted in the generic risk assessment.

The contaminants of concern for the air dispersion modeling prediction section in the main document were: TPM, Cd, Hg, Pb, dioxin and furan, HCl, SO_2, NO_2, and organic matter. These were chosen because they were outlined as such in the MOE Guidelines A-7: Combustion and Air Pollution Control Requirement for New Municipal Incinerators.

For the baseline section, the study noted again that no site had yet been selected. Therefore, there were two stations found that monitored ambient air in the general area where the incinerator might be placed. The highest level for the background air for either site was used for the assumption of what the concentration of chemicals would be in the ambient air surrounding the incinerator to determine possible cumulative effects. The chemicals included in the baseline data were: criteria air contaminants (CACs), VOCs, chlorinated monocyclic aromatics, chlorinated polycyclic aromatics, polycyclic aromatic hydrocarbons, and trace metals. A comprehensive list was not given for this section.

This region's air quality was also described using the Air Quality Index (AQI) reported by the Ministry of the Environment (MOE). There is a description provided of the methodology of the AQI system, and chemicals considered (SO_2, O_3, NO_2, TRS (total reduced sulfur), CO and SP (suspended particles)). There is also a table giving summary data for the region and percentages of incidents where the AQI was poor. No raw data were provided for any of the substances either in the baseline ambient monitoring stations study, or the AQI index discussion.

As there was no site selected, the EA describes the region as a whole. It noted possibly relevant bodies of water, geological conditions, temperature extremes in both Durham and York, as well as precipitation in both regions. Natural features of the area were also described briefly in a short paragraph for each of the following: Lake Iroquois shoreline, South Slopes, Peel Plain, Oak Ridges Moraine, Lake Simcoe and the Simcoe Lowlands, and Peterborough Drumlin field.

A map of the region was provided; however, because there was no site selected, no mention was made of specific land uses, or areas considered to be sensitive receptors. A table was given for the populations in the two regions for the years 1996 and 2001, with the accompanying percentage change.

The contaminants of concern for the baseline study have been identified with reference to the Ontario Ministry of Environment (MOE) and Environment Canada. The seven criteria air contaminants that are predominantly emitted and affect smog, acid rain and climate change are: TPM, PM_{10}, $PM_{2.5}$, CO, NOx, SO_2, and VOCs. For each pollutant in the baseline study, the report identified the sources for each pollutant in tonnes/ha/yr. It did not give information regarding hourly averages or daily averages.

Based on MOE combustion and air pollution control requirements for new municipal waste incinerators, the contaminants of concern are TPM, Cd, Pb, Hg, dioxins and furans, HCl, SO_2, NOx, and organic matter (as CH_4), CO_2, CH_4, N_2O, and HFC.

Table 16. Summary of Impact Identification for the Durham and York Incinerator

Criteria	
1.Impact Identification	**Positive Attributes** The EA presents quantitative data on substances and their sources from different industries in tonnes/year. The EA states criteria for how substances for baseline study were determined. The EA lists all substances included in monitoring program.

	Negative Attributes There are no land use data. There are no population data. There is no site selected. There is no specific model for incinerator and thus no specific emissions data. There are no raw air quality data – presented as Air Quality Index data, which is not useful for vast majority of substances on list of the baseline data.

5.4.2. Prediction

Characteristics of the Incinerator

This analysis is based on the possible emissions from a (hypothetical) modern thermal treatment process with a state-of-the-art air pollution control system, designed to meet all Ontario regulatory requirements. In order to quantify the possible emissions from the facility, the facility is sized based on the envisaged Durham-York ultimate needs (400,000 tonnes/yr) and emission data obtained from thermal treatment technology manufacturers.

It is assumed that this capacity will be sufficient to satisfy disposal needs for residual MSW for the longer term in Durham and York. The facility is assumed to consist of three individual processing lines, each capable of processing 400 tonnes/day of residual MSW for a total capacity of 1,200 tonnes/day. Each processing line will be comprised of an incinerator, heat recovery boiler and an air pollution control system.

Table 17. Physical Specifications of the Durham and York Incinerator

Stack Height	60 m	Exit Diameter	1.35 m
Exit Velocity	15.2 m/s	Exit Temperature	130 oC
Volume of Flow	21.7 m^3/s	Temperature in Incinerator	980 oC
Incineration Time	1 s	Processing Rate	16,666 kg/hr.

The atmospheric dispersion model used in the main air dispersion section in the EA is AERMOD-PRIME. The AERMOD modeling system is made up of the AERMOD dispersion model, the AERMET meteorological pre-processor and the AERMAP terrain pre-processor. AERMOD is a steady-state plume dispersion model that simulates the transport and dispersion of contaminants from multiple point, area or volume sources in both simple and complex terrains.

Since the EA document determined the topography of Durham and York Regions to be relatively flat, a flat terrain is assumed in this generic modeling exercise. The surface conditions meteorological station chosen was Toronto and the upper air conditions metrological station was Buffalo. The modeling was completed using the hourly meteorological data over a 5-year period (1996-2000). The model also used the building heights surrounding the incinerator to take into account building wake effects. Contaminants are averaged over a 24-hour period.

As no particular site has yet been chosen for this project, the report details the generic characteristics of a possible site. The site will be approximately 10 ha of land. For the purpose of this generic air dispersion analysis, it was assumed to be a 300 m x 320 m rectangular property. It was also assumed that the property line was 100 m away from the facility building in all four directions. The height of the freestanding exhaust stack, located 5 m away from the building, was assumed to be 65 m above grade.

It is assumed for this analysis that the thermal treatment facility will operate continuously, 52 weeks per year, 7 days a week, 24 hours a day. For the dispersion modeling exercises, a simultaneous operation of all three processing lines each operating at maximum capacity of 400 tonnes/day is assumed.

The Generic Risk Assessment prediction of pollutants was nearly identical to the previous predictions in its assumptions. One difference was that the emissions data were taken from monitoring done at the KMS Peel incinerator. Multiplying it to be equivalent in scale to that of the planned Durham and York incinerator solved the difference in size of feed tonnage incineration per day.

Type of data used/collection techniques

For the baseline air quality study the primary sources of data used for the main air dispersion study were:

- Environment Canada's National Pollutant Release Inventory;
- The Ontario Ministry of the Environment's OnAir air emissions reporting registry;
- Environment Canada's Criteria Air Contaminants (CAC) Emission Summaries;

- Environment Canada's Canadian Climate Normals meteorological statistics;

- The Ontario Ministry of the Environment's Air Quality in Ontario Reports.

Table 18. Summary of Impact Predication for the Durham and York Incinerator

Criteria	
2.Impact Prediction and Measurement	**Positive Attributes** There are meteorological data for 5 years. The generic health assessment states that emissions estimates come from KMS Peel data. **Negative Attributes** The upper air station data comes from Buffalo, and no mention is given to its acceptability. The meteorological data are not described statistically. The model is stipulated to take in surrounding buildings, but no site was selected so this is unclear.

5.4.3. Impact Description and Evaluation

The results of the two predictions were compared to Ontario provincial regulations and Federal regulations, and it was found that the operation of the selected MSW thermal treatment facility would have a negligible impact on the air quality in the surrounding area. Given that there were neither chosen sites, nor a chosen method of incineration, there was no mention of possible factors that could change this conclusion. The conclusion was not supported by the data provided.

Table 19. Summary of Impact Description for the Durham and York Incinerator

Criteria	
3.Impact Description and Evaluation	**Positive Attributes** The EA states that as compared to Ontario and Canadian regulations, impact is negligible. **Negative Attributes** Given that neither site nor incinerator specifications were chosen, no mention is made as to how predicted impacts may change. There are no substantive data provided.

5.4.4. Management and Mitigation

No specific managing or mitigation measures were discussed. Some possible options were briefly described. None of these options gave information on the amounts of emissions that could be curbed by their usage, rather the descriptions were purely qualitative. However, it was assumed in the calculations that the incinerator would have state-of-the-art emissions control equipment.

Table 20. Summary of Management/Mitigation for the Durham and York Incinerator

Criteria	
4. Management and Mitigation	**Positive Attributes** Possible options for incineration mitigation measures are described in general. **Negative Attributes** No specific management or mitigation measures are discussed in terms of this specific incinerator. No mention is made as to how the choice of mitigation measures will be made.

5.4.5. Monitoring

No monitoring program was outlined.

6. Discussion

6.1. Introduction

This section addresses generalizations that can be made from the observations of all three environmental assessments with reference to the criteria outlined in the methodology section. Any specific references to the individual environmental assessments are made if there are noteworthy differences between them in terms of scope. Specific reference is given to the differences between the proponents' methodologies. An EA is expected to provide adequate description of the study undertakings, and also provide sufficient data and information gathered from those studies to allow the reader to follow the reasoning, and analyze summarized information to determine, to some degree for themselves, the predictions made and the adequacy of conclusions drawn.

6.2. Impact Identification

In terms of impact identification the similarities between the environmental assessments far outweigh the differences. The methodology section suggests there is a need to describe the environment to be affected (including a baseline study), consider boundary definitions, and identify the key impacts of the project. The emphasis in each of the environmental assessments is on the discussion and identification of potentially harmful substances.

The basic elements of the environment modelled as being affected are: the land uses surrounding the undertaking, the climate and meteorological parameters, and populations with consideration of possible sensitive groups. Furthermore, the environment to be affected may be expected to include analysis of natural and seasonal fluctuations. This last element could be considered as a part of the baseline study.

All three environmental assessments included only a cursory discussion of the environment to be affected. The analysis of populations and possibly sensitive groups was almost completely lacking in all three. It is not sufficient to merely state the population, or recent changes in population in the broad political jurisdiction area as a whole without reference to areas most likely to be affected. Of the three EAs studied, only the Sydney EA discussed seasonal fluctuations at all. Land use maps were also the most detailed in this environmental assessment. The Sydney EA also stood apart from the other two in that there was much more detail given to historical air quality considerations, including the types of industry and pollutants emitted into the local air shed. This information was used as part of the method for choosing air contaminants of concern for the prediction section of the environmental assessment.

None of the environmental assessments discuss climate conditions even briefly in the EA document. The basic elements of wind speed and direction, temperature, and precipitation are presented in either a broad historical spectrum average, or detailed information from a particular year. There is little to no discussion of how the data taken from this method (meteorological data typically taken from a nearby airport) or may not be representative of the location where the undertaking is to be situated. There is also no mention of how far the location of the undertaking is from the baseline measurement data, or how similar the topography is at the two locations. In general, there was a dearth of analysis pertaining to the local topography surrounding the undertaking, which could affect the atmospheric dispersion of released contaminants.

For this section of the EA documents, specifically the discussion of atmospheric parameters, it seems that there was an appropriate methodology taken to ascertain the relevant meteorological data required of historic and ambient conditions. However, there was a limited amount of data provided (both spatially and temporally), in summarized form or raw data regarding their influences on the findings of these studies. There was certainly no "statistically adequate description" of atmospheric parameters. The discussion of the difference in baseline monitoring of current conditions is one that could be undertaken during the prediction stage, when these data could be used to determine the impact of the atmospheric contaminants to the surrounding environment.

In none of the EAs were the boundaries of the environment to be affected addressed even in passing. Granted, defining the boundaries when considering a stochastic process such as atmospheric dispersion is far from trivial, some attempt is necessary especially given that the dispersion and subsequent dilution is regarded as the disposal mechanism. It is necessary to note what jurisdiction(s) this area falls into/under such that there can be reference to, and justification for, the contaminants chosen for further study, either in the baseline study or the prediction of impacts later in the EA document. It is also necessary to provide reference to the concentration of contaminants allowed to be emitted, and discuss in more detail the people surrounding the undertaking, and the local industries that could have the potential to work synergistically or antagonistically with the impacts from the proposed undertaking. While population and local industry data were included in most of the EAs, they were not identified based on an analysis of the extent of the environment to be affected, nor with enough detail.

The final section of impact identification is identification of key impacts. This is how the environmental assessments were most similar. They all focused a great deal of the impact identification section on a discussion of specific pollutants. All discussion focused on which chemicals were chosen, and what their key characteristics were. The number of chemicals varied, as did their justification or lack thereof. The Burnaby EA gave no justification, or reference to specific regulations for its choice of chemicals. Most interesting in this EA is the admission that SO_2 in the baseline study had been known to exceed regulatory levels on occasion, but no discussion was given as to whether SO_2 would be considered more carefully during monitoring, or if this was taken into consideration at all.

The chemicals were discussed in the Burnaby EA in terms of what mitigation measures were used, and what affected their formation in the incineration process. The Sydney EA provided a detailed explanation of the reasoning for the list of pollutants considered. This was based on four main factors: if they are frequently present, if they are known to be in either the Tar Ponds or the Coke Ovens site in significant quantities; if they are identified as 'toxic' under CEPA, or if in the past there were exceedences. The Sydney EA did something notable, and not found in the other EAs. It defined significance in the impact identification section. This is an important piece of information for decision-makers to have, and enables them to more fully understand what the stated conclusions of the EA mean.

In the Durham/York EA, the reasoning for the choice of chemicals was stated to be based on the Ministry of the Environment, and Environment Canada's regulations. The most interesting aspect of this EA is that there was consideration of other local sources of these pollutants, for which data were quantitatively given.

Overall, the three EAs failed to present the decision-maker with enough data on the processes of the environment to be affected. The aspect done with the most thoroughness was the discussion of the chosen pollutants. While this section is of great importance, without the supplementary data of other local emitters, local populations and land uses, as well as any considerations as to how the baseline data may not be representative, it is insufficient for a decision-maker to grasp the environment to be affected and make an informed decision if it is not scientifically substantiated.

6.3. Prediction

The prediction section is by far the most detailed of all the sections in any of the EAs studied. An effort was clearly made to show how the final decision was made, and the relevant steps involved. To do this thoroughly requires explicitly noting all methods and techniques, their reasoning, and a discussion of constraining factors. While much of the basic data are presented, a complete picture necessary for an informed decision was not present in any of the environmental assessments. This is not to say that the conclusions drawn, methods or techniques chosen were insufficient or produced significantly erroneous results, merely that they were not explained sufficiently for the decision-maker to be aware of all pitfalls that be result for using the conclusions as presented.

As was discussed in more detail in the methodology section, the two main aspects of prediction are the structural element of the environment and the inputs or emissions from human activity. There are many considerations within these, and each element of data or information used in prediction raises issues of accuracy and uncertainty that accompany them. Of these two very general aspects of prediction, the three EAs were found to do the former adequately, and the latter almost not at all.

The Burnaby EA is different from the other EAs studied in that it specifies at the outset what the objectives of the study are. The three goals are to: define quantity and chemical composition of emissions; estimate ground level concentration and meteorology, and estimate impact. This is helpful for decision-makers to follow the line of reasoning that determines whether there are likely significant negative impacts resulting from the undertaking.

All three EAs make some effort to describe the type of atmospheric dispersion model used for the prediction of impacts; however, they differ in the manner and detail in which they approach this aspect of the EA. The Burnaby EA describes the choice of the two models, and briefly how they are used, and what information is required for each. It goes into sufficient detail describing the worst-case scenario for each model for the reader to follow the chain of evidence.

The Sydney EA is different in that it outlines the type of data required for the application of the atmospheric dispersion model. The stated types of data required are: emission rates; physical geometry of sources of contaminants; spatial relationships of sources and receptors, and meteorological elements. This list is interesting as it allows for an analysis of how well the EA demonstrates and communicates information that it refers to itself, rather than merely considering the aspects outlined in the methodology section. The only data type that the Sydney EA presents with any detail is the meteorological data. There are lists of summaries of wind speed and direction, temperature, and stability. However, the other types of data are vastly insufficient in scope. Emissions data are presented in a cursory manner, and not sufficient to understand the assumptions and choices of methods for predicting them. Receptors are given, as points on a map, but no discussion of how those choices were made, or any mention of the effects of topography in the area.

The Durham/York EA is an interesting example of predictions in an EA in that there are very few specifics given. As was mentioned previously, there is no site selected for either the incinerator, or even the particular type of incinerator to be used. Having said that, there is an abundance of 'local' meteorology presented. Given the lack of project specific data, the absence of discussion of uncertainty in conclusion is all the more striking. This is most apparent in that the model chosen is noted to take into account building heights that will surround the incinerator, but no mention was given as to how this was practically applied to the model results as no site was selected. The prediction methodology for the Generic Health Risk Assessment section was somewhat different. It explicitly stated where the emission data came from. This section only used data from the KMS Peel incinerator. While there is some merit to using actual monitored incineration data, as opposed to emission limits for prediction, there was also no mention of how the Durham/York situation may differ from the data used in prediction. Moreover, none of the models discussed the assumptions inherent in the models, or uncertainties in either the data used or the conclusions drawn.

6.4. Impact Description and Evaluation

The methodology section outlines the need for quantitative evaluation, and a discussion of the various aspects of significance. None of the EAs examined all of the discussed relevant aspects of significance, and none of the EAs provided a quantitative or statistical analysis of impacts. Of all the sections, this was the worst done overall.

All three EAs took the same basic approach when considering significance. Significance, while often broadly defined, was boiled down to whether the predicted concentrations for the chemicals considered were below the relevant regulations.

The Burnaby EA based acceptability on "a comparison between estimated maximum ground level concentration and regulatory guidelines." The Burnaby EA examined the largest number of the significance criteria outlined in the methodology section. This EA stated that cumulative effects were considered, but not how. Duration and frequency are discussed in terms of maintenance. Geographic extent was considered for the box model only. Accidents and malfunctions were considered briefly, and in no way quantitatively. Accidents and malfunctions were only considered to note that some unspecified protocols would be in place to deal with any accidents or malfunctions. Secondary and tertiary impacts were notably absent in the discussion, especially considering the fact that the EA documented earlier on noted how ozone is a problem in this region. Some consideration as to the impact of NOx on the local ozone level would have been warranted. Cumulative effects were mentioned, but no specifics were given.

The Sydney EA only examined malfunctions and accidents, and cumulative impacts of the previously identified aspects of significance. Malfunctions and accidents are discussed very explicitly in terms of what might happen. For instance, there are lists of what the possible likely malfunctions and accidents might be. However, the solutions are dealt with in a similar manner as the Burnaby incinerator EA – in terms of regulations and management protocols. There are no specifics given, and no attention is drawn to what the impacts of these possible malfunctions and accidents might be. Possible cumulative effects are identified as existing sources. The EA document states that these cumulative effects are considered, but not how they are considered. The EA document does state that the results were that they were sufficiently far from the incinerator to not cause negative impacts on air quality.

The final results indicated that no exceedence of any acceptable ground level concentration would occur once the acid control system was in place. The results would "likely" be within the provincial guidelines.

The Durham/York EA merely gave the results in terms of significance as being compared with the Ontario Provincial and Federal regulations, with the conclusion that results would be negligible. There is no mention of possible factors that could change the conclusions drawn, and no substantive data provided about how this conclusion was made. It was often noted that neither site nor specific technology was yet chosen, but no effort was made to consider what ramifications this would have on the predictive process.

There was some variability in terms of which of the previously identified aspects of significance that were considered by the EAs studied. On the whole there was a dearth of substantive data, and limited consideration of malfunctions and accidents. Far more data could have been provided about the significance of the impacts predicted.

6.5. Management and Mitigation

All incineration undertakings involve numerous management and mitigation measures in the design and creation of operation protocols. Yet, there is almost no discussion of how those decisions were made in the three studied EA documents.

The Burnaby EA gives no mention of alternatives, or how the selected management techniques were chosen. There is no substantive data provided about how well they work, and what affects their performance.

The Sydney EA found that SO_2 emissions may exceed regulatory guidelines, and thus implemented the acid control technology. There was no discussion about why this particular technology was used; only that it would reduce the SO_2 emissions by 80% and subsequently operate within the allowable limits. No mention was given as to how it was determined that the amount reduced would be 80%. There was no conclusion as to management or mitigation measures except to note that they "will likely be composed of a baghouse filter, scrubber, and/or cyclone."

The Durham/York EA did not decide on a particular management or mitigation measure, however some possible options were discussed. The description as to the various mitigation possibilities was qualitative and not quantitative. Again, no substantive data were given as to their efficiency, or any considerations about how the choice would be made. The only stipulation was that the incinerator would be built with "state-of-the-art" equipment.

With the exception of Durham/York, there were already many management and mitigation measures in place in the designs of the incinerators. It is surprising that a more thorough description of those measures was not included in the documents. It would provide decision-makers with a better understanding of the project, and associated risks and mitigation measures, as well as the considerations that influenced the choice of the specific management and mitigation measures for the particular undertakings.

6.6. Monitoring

The greatest variability was observed between the executions of the monitoring sections compared with any of the other sections previously discussed. The methodology section outlined a long list of the many reasons why monitoring is necessary. Some of the more compelling reasons were compliance, early warning of un-predicted impacts, information to local inhabitants, and to document the actual impacts for future study. The basic information that should be provided for monitoring would be the selection of chemicals to be monitored, the frequency and technique of monitoring for them, and site selection.

The Durham/York EA document makes no mention of monitoring at all in the discussion of air quality impacts.

In contrast, the Burnaby EA document was the most detailed in its description of the monitoring plan. In order to select the sites for monitoring, the EA adopted an atmospheric dispersion model for the task. The model was described, and its choice was explained as being the model used by US EPA at that time. Uncertainty analysis is even addressed and the document outlines the four main ways that the model may be impacted and made to become less accurate. The document also notes the specific data that were missing, leading to an inability to conduct a thorough study. There were also six recommendations detailing such categories as: what to monitor, a creation of a risk assessment for certain chemicals, what meteorological conditions to monitor, the four permanent sites selected, how to address the lack of certain data, and the creation of a review committee.

The Sydney EA document monitoring plan falls between the other two in terms of detail provided. It stipulated that a long-term monitoring plan would be implemented that followed a National Air Pollution Schedule of monitoring every 6 days, and at milestone times (such as start-up and shutdown). It was noted that the monitoring program had yet to be developed and briefly outlined the manner in which it would be created. The objectives for the monitoring program were stated, and followed along roughly the same lines as what has previously been outlined. There was no mention of where the monitoring should take place, or what chemicals would be monitored.

There was great variety in this section, and only the Burnaby EA provided sufficient information for a decision-maker to understand the process.

7. Conclusions and Recommendations

Three environmental assessment case studies were studied in this project to assess the methodologies used to predict impacts on air quality using case studies. These case studies add to the knowledge regarding the gap between the information presented on the application of predictive measures and the readily available information that literature suggests is critical for decision support.

After analyzing the three EAs studied, there are a number of improvements to the EA process and suggestions for further research that can be made. They can be broadly grouped into two categories: the science practiced, and the science discussed.

The main critique throughout the different stages and aspects of prediction was the lack of evidence in the decision-making process or justification for the conclusions drawn. Without more detail given, it is impossible for a reader to follow completely the methods and techniques chosen for the task of prediction. As this was a problem in all three EAs, it is not possible to give much in the way of an analysis of the science supporting the predictions. This points to future research in the direction of the use of science as a benchmark in EAs. Given that the reader of EAs is not usually going to be an atmospheric scientist, it is appropriate to consider a more textbook-execution approach within the creation of EA documents. While this study only looked at a small cross-section of EAs, what the study's observations may imply is a fundamental problem with EA.

All of the EAs studied used standard atmospheric dispersion models, appropriate for the time of application, yet that is about the only aspect of the prediction that can be validated for certain. The topography, emissions data, and data inputs to the model all showed a lack of relevant detail needed to understand and endorse the results of the model prediction. Much of the decision-making process by the people undertaking the predictive study was omitted from the report. If all the data and decisions made were explicitly outlined in the EA document, one possible outcome is that it would be apparent that the conclusions were based more on a leap of faith given the scant presented data. Without more stringent criteria for the methods involved in report writing, it is not possible to make the claim that the proposed undertakings are environmentally benign.

The simplest solution for a greatly improved EA document would be explicitly explaining the choices of methodology and techniques used in the prediction process. These are all decisions that had to be made along the way for the EA to be completed, and thus their inclusion would represent a limited increase in the amount of work and resources on the part of the proponent. Not only would it allow the decision-maker, given the task of determining the acceptability of the project, to gain a greater understanding of how the conclusions were drawn, but it would also give many other benefits as well. These might include in greater explanation the steps involved in the prediction process, with associated information regarding data quality and sources, which would permit other proponents to learn from previous predictions. This necessitates the undertaking of monitoring studies to see how well the prediction component of the study was conducted, as well as allowing the data to be made available to other parties including the public. While it is recognized that post-project monitoring is not the most practiced of the EA processes, more explicitness in the EA document could lead to greater understanding in the future should more monitoring take place.

As none of the four jurisdictions outlined specifically how the prediction of atmospheric impacts should be undertaken, it leaves the proponent greater opportunity for flexibility in execution. One way for the EA process to achieve more credibility is standardization. The EA process should develop a set of standards that would apply across all jurisdictions. These might include more direction as to how the predictions of point-source emissions impacting air quality are undertaken. Increased standardization in this manner does not mean sacrificing the ability of an EA to address the individual situation of a particular undertaking. It only allows for greater understanding of the results, and ability to learn from other undertakings.

Atmospheric dispersion modelling is a well-studied field. Models have been refined, as technologies have developed, but the crux of the science has remained firmly grounded in Gaussian equations. This allows for the possibility of creating easy-to-follow steps that must be taken when undertaking air quality prediction from point-source emitters, such as incinerators. The issues outlined in the methodology section are a good starting point for creation of a regulatory addition to the environmental assessment legislation and procedures that would ensure more standardization in the process. This does not have to add unnecessary complication or make it more cumbersome to complete an EA. It could do as little as mandating explicit discussion of all techniques and methods used, or as detailed as outlining which methods and techniques are acceptable.

Improving standardization is a first step in an attempt to enhance the ability of the EA system to protect the environment. It is easy to poke holes and find fault in the EA process. Rather than proposing a complete restructuring of the EA system in a way that focuses on strengthening the criteria for an EA to be passed, the thrust of this thesis is based on a much more subtle and incremental changes in the EA process.

Improving the execution of the EA document allows for greater transparency in the way that EA decisions are actually made, without demanding changes to that process. This suggestion would allow for future research to be made more thoroughly into the nature of science in EA, and begin to see some differences and limitations between pure and applied science as applied to EA. This could then facilitate the insurance of scientifically sound practices, ensuring data and prediction quality while acknowledging the common temporal and financial limitations of the EA system. A further next step could be to improve post-project monitoring, or add within the legislation that EAs demonstrate that they have researched, and analyzed the process and findings of other similar projects. The EA process can only improve dramatically if all of the pieces are included. Yet, if there were an environmental disaster resulting from an undertaking, improved EA report writing would be an invaluable tool to understand how such an event happened, and to identify ways to prevent future disasters. However, this step is only viable for some portions of some EA undertakings, those that involve very well understood processes – such as atmospheric dispersion.

An EA's goals are to improve the consideration of the environment, for its protection, in the creation and operation of new undertakings. Clearly outlining the reasoning of the process of prediction, and the conclusions drawn, is the only way for the EA process to achieve the goals of managing and mitigating impacts to air quality from incineration. Most of the decisions are made with sound scientific reasoning; but without logical and irrefutable evidence, EA professionals miss a great opportunity to learn from past experiences, and enhance the science of prediction.

References

Basta, D. and B. Bower, 1982. *Analyzing Natural Systems.* Resources for the Future Washington, D.C.

Beanlands, Gordon E. and Peter N. Duinker, 1983. *An Ecological Framework for Environmental Impact Assessment in Canada.* Dalhousie University Halifax.

Briassoulis, Helen, 1995. "Environmental Criteria in Industrial Facility Siting Decision: An Analysis" *Environmental Management* 19:2 pp. 297-311.

British Columbia Environmental Assessment Office, 2003. *Summary Guide to the British Columbia Environmental Assessment Process.* British Columbia Environmental Assessment Office

Canadian Environmental Assessment Act, 1992, c. 37, C-5.2

Canter, L. W., 1996. *Environmental Impact Assessment.* McGraw-Hill New York.

Cashmore, M., 2004. "The Role of Science in Environmental Impact Assessment: Process and Procedure versus Purpose in the Development Theory" *Environmental Impact Assessment Review* 24 pp. 403 - 426.

Cimorelli, Alan J., Steven G. Perry, Akula Venkatram, Jeffrey C. Weil, Robert J. Paine, Robert B. Wilson, Russell F. Lee, Warren D. Reters and Roger W. Brode, 2005. "AERMOD: A Dispersion Model for Industrial Source Applications. Part 1: General Model Formation and Boundary Layer Characterization" *Journal of Applied Meteorology* 144 pp. 682-693.

De Jongh, P., 1988. *Uncertainty in EIA.* Unwin Hyman London.

Drew, Christina H. and Timothy L. Nyerges, 2004. "Transparency of Environmental Decision Making: A Case Study of Soil Cleaning Inside of Hanford 100 Area" *Journal of Risk Research* 7 pp. 33-71.

Duinker, Peter N. and Lorne A. Greig, 2006. "The Impotence of Cumulative Effects Assessment in Canada: Ailments and Ideas for Redeployment" *Environmental Management* 37:2 pp. 153-161.

Durham and York Regions 2005. *Residual Waste Study.* Durham and York Regions
Romanowicz, Renata, Helen Higson and Ian Teasdale, 2000. "Bayesian Uncertainty Estimation Methodology Applied to Air Pollution Modelling" *Environmetrics* 11 pp. 351-371.

Elkin, T.J. and P.G.R. Smith, 1988. "What is a Good Environmental Impact Statement? Reviewing Screening Reports from Canada's National Parks" *Journal of Environmental Management* 26 pp. 71-89.

Elliot, Michael, 2003. "Risk Perception Frames in Environmental Decision-Making" *Environmental Practice* 5:3 pp. 214-222.

Elsom, Derek M., 1995. "Air and Climate" in *Methods of Environmental Impact Assessment*, P. Morris and R. Therivel. UCC Press Lond. 120-142.
Environmental Assessment Act, SBC 2002, c. 43

Fox, Douglas G., 1980. "Judging Air Quality Model Performance" *Bulletin American Meteorological Society* 62:5 pp. 599-609.

Fox, Douglas G., 1982. "A Summary of the AMS Workshop on Quantifying and Communicating Model Uncertainty" *Bulletin American Meteorological Society* 65:1 pp. 27-35.

Fuller, Karl, 1997. "Quality and Quality Control in Environmental Impact Assessment" in *Handbook of Environmental Impact Assessment, Volume 2: Environmental Impact Assessment in Practice: Impact Limitations*, J. Petts. Blackwell Science Ltd. Oxford. 55-82.

George, C., 2000. "Environmental Impact Prediction and Evaluation" in *Environmental Assessment in Developing and Transitional Countries: Principles, Methods, and Practice*, N. Lee and C. George. Wiley Chichester. 85-110.

Gibson, Robert B. and Kevin S. Hanna, 2005. "Progress and Uncertainty: The Evolution of Federal Environmental Assessment in Canada" in *Environmental Impact Assessment: Practice and Participation*, K. S. Hanna. Oxford University Press New York. 16-32.

Glasson, John, 1999. "Environmental Impact Assessment - Impact on Decision" in *Handbook of Environmental Impact Assessment, Volume 1: Environmental Impact Assessment: Process, Methods and Potential*, J. Petts. Blackwell Science Ltd. Oxford. 121-144.

Graci, S., 2005. "The Ontario Environmental Assessment Act" in *Environmental Impact Assessment: Practice and Participation*, K. Hanna. Oxford University Press New York. 308-326.

Greater Vancouver Regional District, 1986a. *Assessment and Recommendations on Emission and Monitoring Requirements for Greater Vancouver Regional District Incinerator Located in Burnaby*. Greater Vancouver Regional District

Greater Vancouver Regional District, 1986b. *Supplementary to the report on Emission and Monitoring Requirements for Greater Vancouver Regional District Incinerator Located in Burnaby.* Greater Vancouver Regional District

Harrop, D. Owen, 1997. "Air Quality Assessment" in *Handbook of Environmental Impact Assessment, Volume 1: Environmental Impact Assessment: Process Methods and Potential*, J. Petts. Blackwell Science Ltd. Oxford. 252-272.

Harrop, D. Owen and J. A. Nixon, 1999. *Environmental Assessment in Practice.* Routledge New York.

Herring, Jamie, 2005. "The Canadian Federal EIA System" in *Environmental Impact Assessment: Practice and Participation*, K. Hanna. Oxford University Press New York. 231-247.

Holling, C. S., 1978. *Adaptive Environmental Assessment and Management.* Wiley and Sons Toronto.

Inhaber, Herbert, 1997. *Slaying the NIMBY Dragon.* Transaction Publishers New Brunswick.

Jain, R. K., L. V. Urban, G. S. Stacey and H. E. Balbach, 1993. *Environmental Assessment.* McGraw-Hill Inc. New York.

KMS Peel Inc., 2000. *Environmental Assessment Act Application Expansion of the KMS Peel, Inc, Brampton Energy-From-Waste Facility.* KMS Peel Inc. Brampton.
Fischhoff, B., 1995. "Risk Perception and Communication Unplugged: 20 Years of Process" *Risk Analysis* 15 pp. 137-145.

Kuhn, Richard and Kevin Ballard, 1998. "Canadian Innovations in Siting Hazardous Waste Facilities" *Environmental Management* 22:4 pp. 533-545.

Ladd, A. and S. Laska, 1991. "Opposition to Solid Waste Incineration: Preimplementation Anxieties Surrounding a New Environmental Controversy" *Sociological Inquiry* 61:3 pp. 299-313.

Lundgren, R. and A. McMakin, 1998. "Principles of Risk Communication" in *Risk Communication*, R. Lundgren and A. McMakin. Battle Press Columbus. 81-96.

Marriott, Betty Bowers, 1997. *Environmental Impact Assessment: A Practical Guide.* McGraw-Hill New York.

McFarland, Michael J., Tim M. Nelson and Glen R. Palmer, 2004. "Development of a Hazardous Air Pollutants Monitoring Program Using the Data Quality Objectives Process" *Journal of the Air and Waste Management Association* 54:5 pp. 614-622.

Meredith, T., 2004. "Assessing Environmental Impacts in Canada" in *Resource and Environmental Management in Canada*, B. Mitchell. Oxford University Press Don Mills. 467-496.

Mitchell, B., 2004. "Introduction to Policy Context, Issues and Challenges" in *Resource and Environmental Management in Canada*, B. Mitchell. Oxford University Press Don Mills. 1-18.

Morgan, Richard K., 1998. *Environmental Impact Assessment: A Methodological Perspective*. Kluwer Academic Publishers London.

Moussiopoulos, Nicolas, Erik Berge, Trund Bohler, Frank de Leeuw, Knut-Erik Grunskei, Sufia Mylona and Maria Tombrou, 1996. *Ambient Air Quality, Pollutant Dispersion and Transport Models*. European Environmental Agency Copenhagen.

National Research Council (U.S.), 2000. *Waste Incineration and Public Health*. National Academy Press Washington.

Noble, Bram F., 2006. *Introduction to Environmental Impact Assessment: A Guide to Principles and Practice*. Oxford University Press New York.

Pielke, R., 1998. "The Need to Assess Uncertainty in Air Quality Evaluations" *Atmospheric Environment* 32:8 pp. 1467-1468.

Pushchak, Ronald and Cecilia Rocha, 1998. "Failing to Site Hazardous Waste Facilities Voluntarily: Implications of the production of Sustainable Goods" *Journal of Environmental Planning and Management* 41:1 pp. 25-44.

Rabe, Barry George, 1994. *Beyond NIMBY: Hazardous Waste Siting in Canada and the U.S.* University of British Columbia Vancouver.

Rao, K. Shankar, 2005. "Uncertainty Analysis in Atmospheric Dispersion Modeling" *Pure and Applied Geophysics* 162:10 pp. 1893-1917.

Rao, K.S. and R.P. Husker, 1993. "Uncertainty in the Assessment of Atmospheric Concentration of Toxic Contaminants from an Accidental Release" *Radiation Protection Dosimetry* 50:2-4 pp. 281-288.

Ross, W. A., 1987. "Evaluating Environmental Impact Statements" *Journal of Environmental Management* 25 pp. 137-147.

Sadler, B., 1996. *International Study of the Effectiveness of Environmental Assessment, Environmental Assessment in a Changing World, Evaluating Practice to Improve Performance*. International Association for Impact Assessment and Canadian Environmental Assessment Agency Ottawa.

Seaman, Nelson L., 2000. "Meteorological Modeling for Air-Quality Assessments" *Atmospheric Environment* 34 pp. 2231-2259.

Shopley, J. B. and R. F. Fuggel, 1984. "A Comprehensive Review of Current Environmental Impact Assessment Methods and Techniques" *Journal of Environmental Management* 18 pp. 25-47.

Sippe, R., 1997. "Criteria and Standards for Assessing Significant Impact" in *Handbook of Environmental Impact Assessment, Volume 1: Environmental Impact Assessment: Process, Methods and Potential*, J. Petts. Blackwell Science Ltd. Oxford. 74-92.

Sydney Tar Ponds Agency, 2005. *Remediation of Sydney Tar Pond and Coke Ovens Sites Environmental Impact Statement*. Sydney Tar Ponds Agency

Weil, J.C., R.I Sykes and A. Venkatram, 1992. "Evaluating Air-Quality Models: Review and Outlook" *Journal of Applied Meteorology* 31 pp. 1121-1145.

Weston, J., 2000. "EIA, Decision-making Theory and Screenings and Scoping in UK Practice" *Journal of Environmental Planning and Management* 43 pp. 185-203.

Wood, C., 1999. "Comparative Evaluation of Environmental Impact Assessment Systems" in *Handbook of Environmental Impact Assessment, Volume 2: Environmental Impact Assessment in Practice: Impact and Limitations*, J. Petts. Blackwell Science Ltd. Oxford. 10-34.