ENVIRONMENTAL RISKS OF MUNICIPAL NON-HAZARDOUS WASTE LANDFILLING AND INCINERATION

TECHNICAL REPORT SUMMARY

JULY 1999

Ontario

Ministry
of the
Environment

ISBN 0-7778-8958-7

ENVIRONMENTAL RISKS

OF MUNICIPAL NON-HAZARDOUS WASTE

LANDFILLING AND INCINERATION

TECHNICAL REPORT SUMMARY

Standards Development Branch
Environmental Sciences and Standards Division
Ontario Ministry of the Environment

JULY 1999

Cette publication technique
n'est disponible qu'en anglais.

PIBS 3795E01

ACKNOWLEDGEMENTS

This summary incorporates material from all parts of the Technical Report and was prepared by Dr. Brendan Birmingham, Mr. Robert Duff, P. Eng. and Mr. Doug Harper of the Standards Development Branch, Ontario Ministry of the Environment.

The full Technical Report was prepared by staff of the Standards Development Branch, Ontario Ministry of the Environment. Overall project co-ordination was facilitated by Dr. Brendan Birmingham.

Final document preparation was done by Mr. Adam Socha and Dr. Brendan Birmingham.

For more information, contact:

Standards Development Branch
Ontario Ministry of the Environment
135 St. Clair Ave. West,
Toronto, Ontario M4V 1P5

Tel: (416) 327-5519

ABSTRACT

It is the position of the Ministry of the Environment that both landfilling and incineration options be available for consideration so that a municipality or other proponent can develop the best environmental solution for its locality.

The Ministry conducted a series of technical risk assessments of two generic disposal facilities: a large-scale incinerator and modern landfill with a similar disposal capacity of 6.6 million tonnes over 20 years.

Potential emissions from these hypothetical facilities were assessed for their potential impacts on human health and on the environment. Negligible effects are predicted for facilities that meet stringent requirements and standards for design, operation and pollution control. Therefore, concerns for human health and the environment should not limit the selection and approval of incinerators or landfills. Specifically:

- No significant human health effects (those being cancer, lung disease, nerve damage or reproductive effects) are likely in a typical suburban community located near an incinerator or a landfill. Under certain conditions, nuisance problems linked to malodorous compounds may affect air quality close to a landfill.

- An ecological risk assessment predicts that water and sediment quality near an incinerator or landfill will meet Ministry guidelines for the protection of aquatic life.

- Direct or indirect impacts to the terrestrial environment, vegetation or wildlife resulting from incinerator or landfill emissions are not anticipated to be significant. The main differences in terrestrial impacts between the two waste disposal methods relate to the amount of land used and to the production of nitrogen oxides.

TABLE OF CONTENTS

SUMMARY

In the hierarchy of preferred waste management options, incineration and landfilling follow the 3Rs -- waste reduction, reuse and recycling. Despite the success of waste diversion efforts, however, residual wastes still require disposal.

Up-to-date information is needed on the potential environmental and human health impacts of the incineration and landfilling for municipal waste disposal. To obtain this information, the ministry conducted a series of technical risk assessments of two generic disposal facilities: a large-scale incinerator and a modern landfill, each with a similar disposal capacity of 6.6 million tonnes over 20 years.

Section 2 of this document provides summaries of the main assumptions, methods and conclusions of the full technical studies for the landfill and incinerator risk assessments. A full Technical Report is available which includes technical studies of the health impacts of the generic incinerator and landfill (Technical Report Parts A and B) and of the aquatic and terrestrial effects of both technologies (Technical Report Parts C and D). Technical Report Part E contains glossaries of technical terms used in the risk assessments.

The risk assessments show that properly designed and operated municipal waste incinerators and landfills should not have a significant effect on human health and the environment. Beyond these analyses, new municipal waste incinerators and landfills will be required to meet Ontario's stricter *Guideline A-7* and *Landfill Standards* guideline requirements. Consequently, new facilities will present even less risks than those identified in these analyses.

1.1 Effects on human health

The human health assessments show that no adverse health effects (including cancer, lung disease, nerve damage and reproductive effects) are expected to result from long-term exposure to emissions from either type of facility.

Estimates of the total lifetime incremental cancer risk for a maximally exposed individual, from long-term exposure to incinerator emissions, range from 4.7×10^{-8} to 2.3×10^{-7}. Estimated exposure to emissions of non-carcinogenic chemicals were below generally accepted levels of concern.

Estimates of the total combined cancer risk from long-term exposure to landfill emissions containing volatile chlorinated chemicals range from 4.0×10^{-6} to 1.0×10^{-5}.

Landfills could result in complaints about odours and subjective symptoms but no adverse health effects are expected.

1.2 Effects on the aquatic environment

Water and sediment quality around an appropriately designed and operated landfill or incinerator is expected to meet ministry guidelines for aquatic life. However, mercury and dioxin/furan levels after 20 years of incineration operation, might slightly exceed U.S. EPA water quality guidelines that were developed to protect wildlife which consume fish.

1.3 Effects on the terrestrial environment

Estimated chemical emissions from either a landfill or an incinerator will not cause adverse effects on nearby vegetation, wildlife or other terrestrial biota. Further assessment may be required to determine the risk to wildlife that consume soil-dwelling organisms at sites where the background levels of persistent toxic chemicals in the soil are higher than normal.

While the operation of a landfill requires at least four times the land space of an incinerator, upon closure the area can be reclaimed as green space, partially compensating for loss of habitat.

Incinerators emit more nitrogen oxides than do landfills. However, total emissions of nitrogen oxides from incinerators would be a small compared to the total nitrogen oxide emissions in Ontario. Given that small contribution, it was not possible to statistically separately evaluate the potential adverse effects on sensitive upland hardwood forests which may already be under stress from current nitrogen oxide levels.

A detailed comparative analysis of greenhouse gas emissions from landfills and incinerators was not within the scope of this study. However, when estimated emissions of CO_2 and methane are converted to greenhouse gas equivalents, and the uncertainty associated with emission estimates are taken into consideration, both disposal methods are roughly equal with respect to the release of greenhouse gases.

RISK ASSESSMENTS

2.1 Introduction

Ministry staff have undertaken extensive technical studies to quantify and evaluate the potential adverse effects of incineration and landfilling of municipal solid waste, on human health and the natural environment. The study provides interested parties with baseline technical information needed to support the decisions on waste disposal.

Risk assessments were conducted on human health effects, terrestrial effects and aquatic effects. The release of toxic chemicals to the environment was the prime concern, but other risks were evaluated including: odour and nuisance problems, the loss of habitat and greenhouse gas emissions.

The assessment of potential environmental and health effects followed accepted scientific procedures used by risk assessment experts and government agencies in Canada and the United States. Screening protocols and sophisticated modelling simulated a range of environmental exposures and corresponding risk levels.

Realistic scenarios concerning disposal facilities, locations, emissions, populations affected and a wide range of environmental and human health effects were examined. For each scenario, staff estimated potential chemical exposures and weighed them against stringent toxicological criteria designed to protect human health and the environment.

2.2 Sources of information

The ministry maintains extensive scientific, technical and regulatory information on the environmental and human health effects associated with the disposal of municipal solid wastes. The assessments provided in Parts A through D of the technical report include detailed bibliographies and appendices.

The assessments were based on currently available information in the Ministry's data bases. Wherever possible, Ontario data were used. Where additional information was required, it was obtained from the scientific literature or other sources available to the Ministry.

It was decided that new field or raw data would not be developed for the study.

2.3 Risk assessment assumptions

Risk assessment is a formal, scientific process to analyse the potential for harm following exposure to chemicals or other agents. A number of basic assumptions are used to define and set the limits of the study, and the findings are valid only in accordance with these underlying assumptions.

For the purpose of these assessments, a hypothetical incinerator and a landfill of equivalent size (capable of disposing of 6.6 million tonnes of municipal waste over 20 years), were assumed to be sited in Ontario. The assessments use the same data bases for meteorological, population, topographical, land area and surface water information. Because extensive, site-specific data had been collected recently in a series of technical reports prepared in support of a southern Ontario landfill proposal, these reports were the major source of data for the studies. A population base of 550,000 residents was used for the study.

The incinerator and landfill assessments were designed to be comparable, but specific assumptions were needed to account for differences between the waste disposal methods. For example, the potential effects of incineration commence immediately with startup and end when the facility shuts down. In contrast, landfill emissions peak later in the operating life of the facility (after about twenty years) and decline slowly following closure.

While risk assessment is a rigorous scientific discipline, it has certain limitations. All risk assessment procedures contain uncertainties due to, for example, limited information on the release of specific contaminants to the environment, their exposure pathways and toxicological effects. Therefore, the exercise yields only an estimate of the risk and not the actual effect associated with a specific proposed or existing facility.

To compensate for uncertainties, "worst case" or "reasonable worst-case" chemical exposures area assumed. The use of higher-than-expected exposure conditions emphasizes any potential problems and identifies potentially dangerous chemicals or sensitive exposure pathways for more detailed study.

In most cases, this will result in overestimating the actual risks. A projected exposure level that exceeds an environmental or human health protection standard represents a warning flag, rather than an actual risk or effect.

For the purposes of this report, background levels of chemicals were not evaluated because they are site-specific and variable, depending on the presence of natural and manufactured sources. When assessing a particular proposed site the local background levels will contribute to the overall environmental health risk.

The primary sources of operating data and major assumptions are described for the landfill and incinerator, below. All other assumptions used in the analyses (such as deposition rates or health criteria) are noted elsewhere in the attached assessment reports.

The incinerator

Wastes have been burned in Ontario for a long time. The technology has evolved from burning piles of refuse in open pits to highly-engineered plants that incorporate extensive computer controls, pollution control equipment and continuous emission monitoring. There are two main types of incinerators widely used around the world: mass burn units and modular starved air units.

- The hypothetical incinerator used for the analyses is a state-of-the-art facility with well operated, advanced pollution control equipment.

- The incinerator would have disposal capacity of 6.6 million tonnes of municipal solid waste, over an operational life of 20 years (to correspond with the capacity of the landfill).

- The estimates of air emissions were based on stack monitoring data for a medium-sized and a larger facility, burning waste at a 400 and 1500 tonnes per day, respectively.

- The analysis used the latest emission testing data from incinerators operated in Brampton, Ontario, and Hartford, Connecticut. Both facilities burn municipal wastes: the Hartford facility employs mass burn technology, while the Brampton facility uses starved air. Both plants have modern pollution control equipment, including wet scrubbing, lime injection and bag filtration systems. Extensive data derived from emission monitoring at both facilities was compiled to determine the most significant pollutants for further consideration.

- The dispersion of incinerator air emissions was calculated using the ministry's standard modelling approach.

- Neither of the incinerators on which much of the analysis was based currently employs nitrogen oxide controls or adds activated carbon to the scrubber (used, primarily, to reduce mercury and dioxin/furan levels). As a result, the emissions and associated risks are higher than any new incinerator facility in Ontario which would have to meet the province's more stringent approval and operating standards.

The landfill

Disposal of municipal refuse into landfills has also been carried out in Ontario for a long time. As a technology, it has evolved from simply dumping waste onto the ground to engineered facility designed and operated to protect the environment.

The landfill studied in the risk assessment is generic, but the analysis is based on data generated during the development of landfill proposals for a Southern Ontario area. This provided an up-to-date and extensive data base which had been reviewed recently by Ministry staff involved in the landfill approval process.

- The hypothetical landfill used for the analyses is a state-of-the-art facility with advanced pollution control equipment that is well operated without failure.

- The landfill would have a disposal capacity of 6.6 million tonnes of municipal wastes, over an operational life of 20 years (to correspond with the capacity of the incinerator).

- The impact assessment for the landfill assumes an environmental emission period extending 20 years beyond closure.

- Data on terrestrial and aquatic effects are based on a landfill proposed in reports to the Interim Waste Authority.

- Leachate is collected, treated on-site and then discharged to a municipal sewer system. The stormwater is collected and treated in a settling pond prior to discharge to a local water course.

- Landfill gas collection starts in the fourth year of operation and continues 20 years after closure. The gas collection system recovers 70 per cent of the gas produced, while the remaining 30 per cent escapes to the atmosphere. The collected gas is burned in a flare, without any pollution control system.

- Estimates of landfill gas emissions are based on data derived from the Britannia Road landfill in the Region of Peel, Ontario.

- The dispersion of landfill air emissions was calculated using the Ministry's standard modelling approach.

2.4 Environmental fate of emissions

The levels of chemical contaminants to which humans and wildlife are exposed depend on the environmental fate of incinerator and landfill emissions. To estimate exposures, mathematical models were used to simulate the dispersion of emissions into the environment surrounding each waste facility. The models estimated chemical concentrations in air, soil, water, sediment and the food chain. Southern Ontario weather data were used in the modelling.

The environmental pathways of incinerator and landfill emissions to humans and wildlife are illustrated in Figures 1 to 4 below.

Figure 1: Aquatic exposure pathways

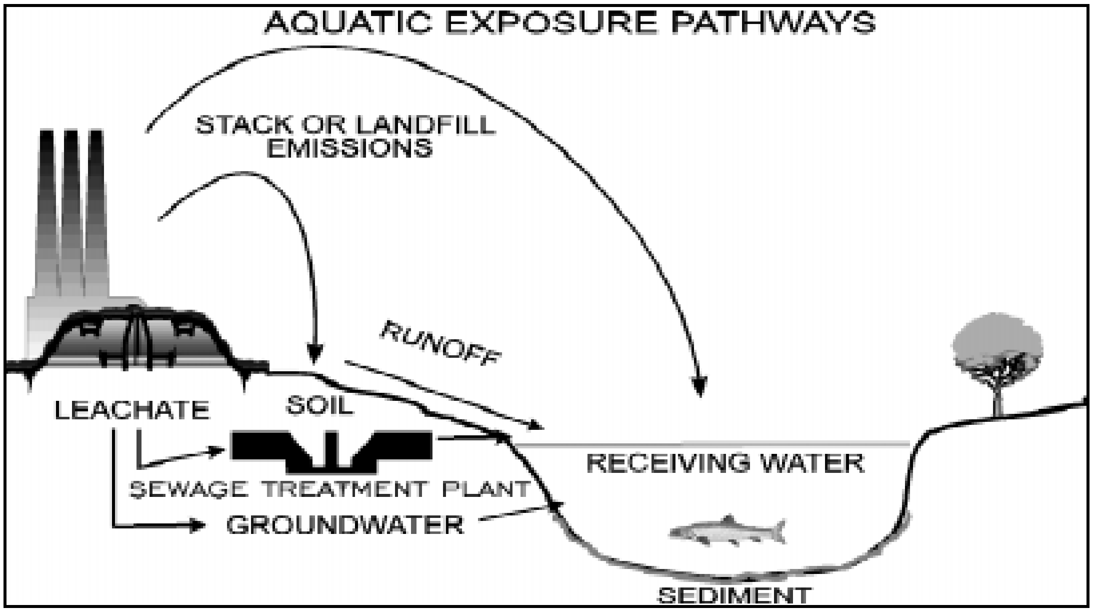


Figure 2: Terrestrial exposure pathways

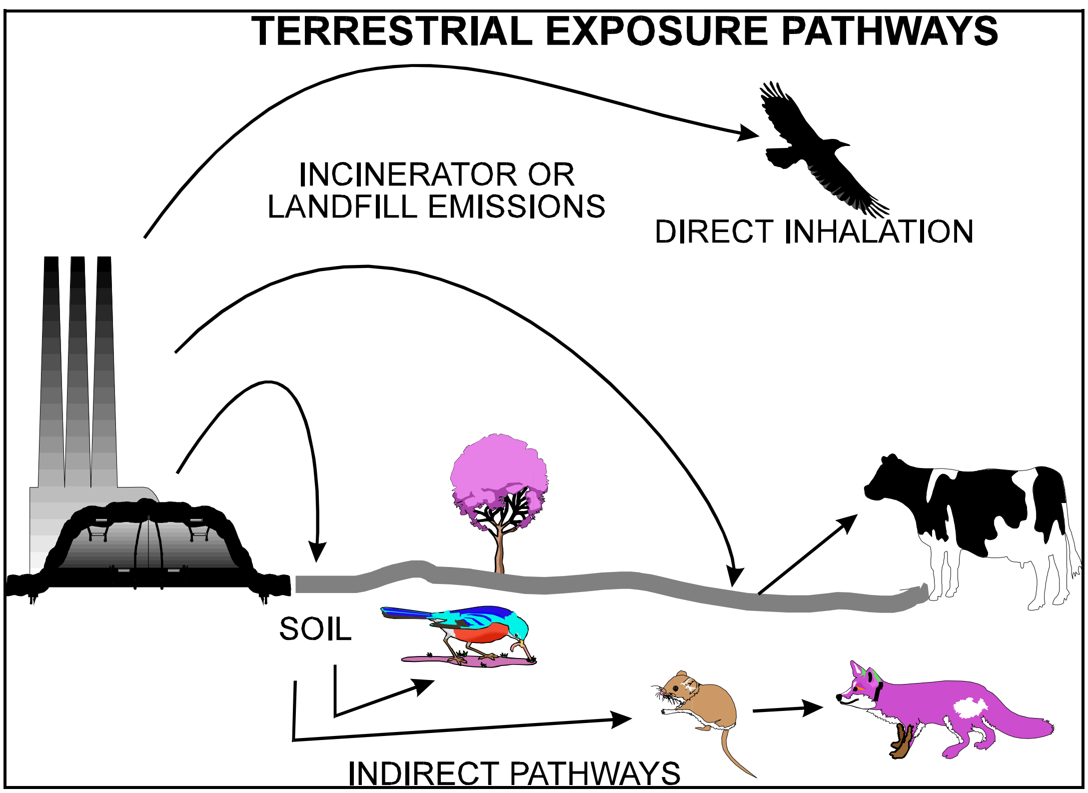


Figure 3: Incinerator exposure pathways

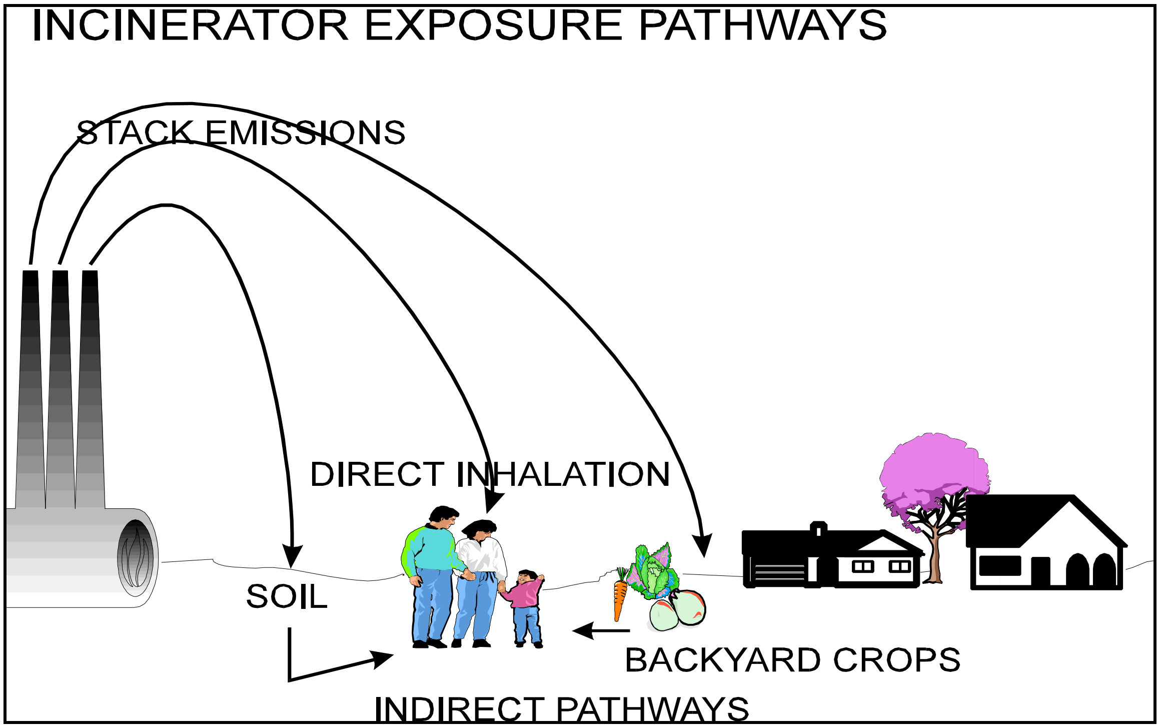
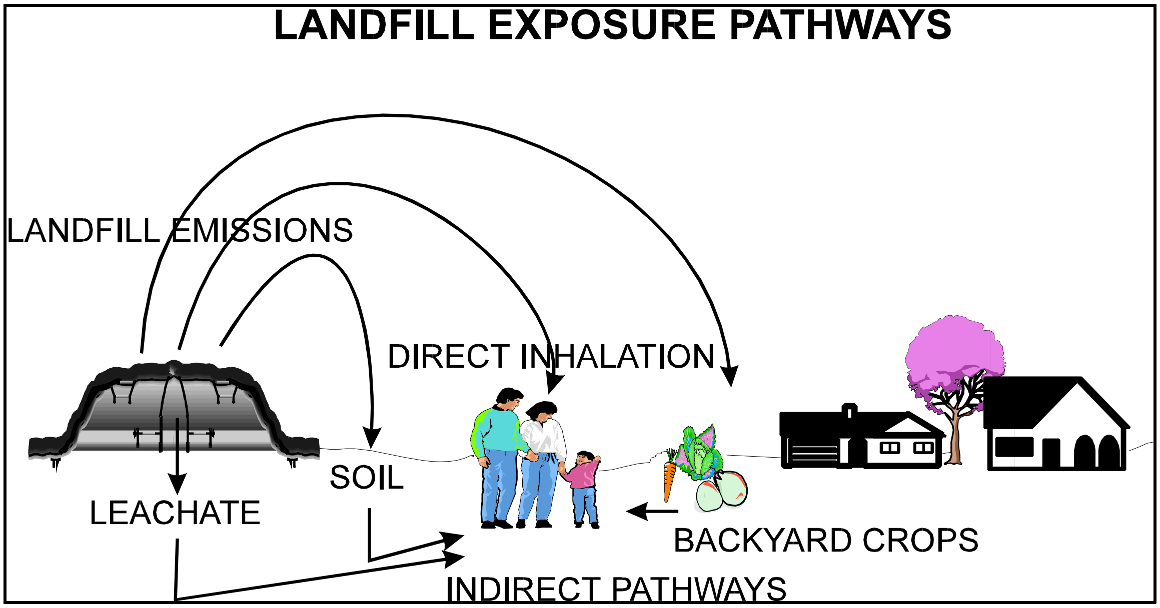


Figure 4: Landfill exposure pathways



The incinerator

A municipal solid waste (MSW) incinerator emits gases and small particles, including trace levels of metals and organic chemicals into the atmosphere from a smoke stack, usually more than 30 metres above ground level. These emissions are transported downwind and dispersed, according to weather conditions and the local terrain. The bulk of the emissions are spread widely over long distances, contributing to overall provincial air pollution. However, some of the emissions reach ground level within a few kilometres of the stack, creating an area of maximum ground-level air concentrations. This area of maximum exposure may include urban communities, rural areas, forests, lakes and streams.

Incineration produces both fly ash, the small particles filtered out by the air pollution control equipment, and bottom ash as solid waste residues. Bottom ash is considered nonhazardous and can be landfilled along with municipal solid waste. The chemicals in the ash are not expected to migrate or “leach” from the landfill by water drainage because of their low mobility in soils and their containment within the clay liners of a well-designed landfill.

Fly ash is tested for leachate toxicity. If tests show it is toxic, it must be disposed of in a secure, hazardous waste landfill.

The landfill

Over the course of its operating life and following closure, a municipal solid waste landfill releases gases and particles to the air through out-gassing, and to the soil and groundwater, through leaching. Traces of organic compounds and metals are found in the emissions.

Most of the organic gases, such as methane in the air emissions, are captured and burned-off in flares; with the remainder dispersed downwind. Compared to an incinerator, the area of maximum exposure would be much closer to the source, near the property line of the landfill.

Some landfill chemicals are mobile in leachate and must be collected and treated. Leachate that escapes a faulty landfill may contaminate groundwater and surface water.

2.5 The assessment of effects on human health

Potential human health effects associated with the operation of the hypothetical incinerator and landfill were assessed by:

(1) screening lists of possible chemical emissions and preparing a shorter list of priority chemicals;

(2) estimating levels of environmental contamination by these priority chemicals to which people might be exposed;

(3) comparing the exposure (intake) to established health protection criteria.

To estimate human exposure, information was needed on the chemical concentrations in air, water, soil and food. There is no single correct level for each concentration, but a range of possible values that will vary according to location and environmental condition.

The conventional method for assessing health impacts is to use a “worst-case” level for each chemical of concern and make a single estimate of maximum risk. For this study, more realistic values were used for some of the exposure concentrations to make a “reasonable worst-case” exposure scenario for each priority chemical.

A second, more sophisticated method was used to estimate human exposure and health risks. A computer model, using a “Monte Carlo” methodology, analysed the range of possible levels for each exposure variable and generated a corresponding range of risk estimates for each chemical. This provided more information (for example, midpoint and 95^{th} percentile risks) than the conventional method that examines only one scenario for each chemical.

The reasonable worst-case exposure scenarios were also included in the Monte Carlo analysis. This ensured that the findings of both methods could be compared to published risk assessments.

The most up-to-date federal, Ontario and U.S. human health protection information were used to assess health risks. Several different health effects were considered, including cancer. For chemicals that cause cancer (carcinogens), human exposures were converted into a lifetime cancer risk. Many jurisdictions consider a lifetime risk of one in one hundred thousand (0.00001 or 10^{-5}) or less to be negligible or not significant.

For chemicals that can cause other toxic effects – such as lung disease, birth defects or nerve damage – chemical exposures were compared to existing health protection standards to calculate an exposure ratio. A ratio of less than one (1.0) means that no adverse health effects are expected.

Cancer risks or exposure ratios were calculated for each chemical. To assess the combined overall health impact, the cancer risks and exposure ratios were added together for different chemicals with similar toxic effects.

In this report, the term "dioxin" refers to the large but closely related dioxin and furan family of compounds. Although certain dioxin compounds may cause cancer, it is believed that a threshold or minimum level is necessary for this occur. Studies indicate that the impact of dioxin on the reproductive system may be just as significant as its carcinogenic effects. Therefore, dioxin toxicity was evaluated using exposure ratios and a stringent health protection standard.

The lifetime cancer risk for the community (of approximately 550,000 residents) living near the facility was also estimated using the Monte Carlo method. The midpoint and upper limits (that is the 95^{th} and 97^{th} percentile) of population risk were expressed as the number of cancer cases that might be expected due to chemical emissions during the operating life of the facility.

The possibility of nuisance odours was evaluated for landfilling but not incineration.

The incinerator

Since incineration generates a wide variety of chemicals, many of them in trace amounts in the off-gases and ashes produced, it would be a practical impossibility to evaluate them all. This assessment focussed on the chemicals in stack emissions that are either abundant or can cause serious human health effects. A master list of 130 incinerator chemicals was reduced to 70 chemicals for a second screening step.

The second screening identified those chemicals that may be present in significant levels or represent health risks to a maximally exposed individual breathing air contaminated by incinerator emissions. This screening step resulted in the compilation of a short list of 15 priority chemicals for detailed study (see Table 1 in the Appendix). Together, these priority chemicals accounted for 99 per cent of the risk related to the inhalation of toxic emissions. Cancer, lung disease and nerve damage are the main health hazards posed by these 15 chemicals.

The dispersion of the priority incinerator emissions into air and the surrounding community was simulated using mathematical models. The airborne concentrations were calculated for the area of maximum exposure near the incinerator. In turn, these levels were used to estimate the resulting contamination of local soil and of fruits and vegetables grown in backyard gardens.

People would be exposed to the chemicals primarily by breathing air (inhalation) and eating garden produce (ingestion). Chemical exposure may also result from skin contact with contaminated soil and from the accidental ingestion of soil. Because a suburban lifestyle was assumed, other exposure routes not directly affected by incineration emissions, were considered insignificant.

The typical suburban diet would consist primarily of supermarket foods, treated tap water and other sources unaffected by the incinerator emissions. Local sources of food and water may be contaminated, but would represent a smaller part of the average suburban diet (as compared to the diet of someone who lived on a farm or who consumed significant amounts of game or sport fish).

The results of the human health assessment are summarized in Technical Report Part A.

For the "reasonable worst-case" exposure scenario, the main findings are as follows:

- The combined cancer risk was 8.3×10^{-8} (*i.e.*, 1 in 12 million). Almost all of the lifetime cancer risk was related to inhalation; other exposure routes added little to the risk.

- The combined exposure ratio (the ratio of the estimated exposures to published health protection limits) was 0.1 for those priority chemicals with effects other than cancer. A ratio more than 1.0 is considered to be above accepted exposure limits.

- The intake of dioxin was less than one per cent of the recommended exposure limit. Dioxin intake was due mostly to indirect exposure from backyard garden produce and soil.

- For lead and mercury, soil and garden produce contributed over half of the exposure ratio.

The main findings of the computerized *Monte Carlo* exposure assessment are as follows:

- The combined cancer risk ranged from a midpoint value of 4.7×10^{-8} (one in 21 million) to an upper limit of 2.3×10^{-7} (one in 4.4 million).

- The combined exposure ratio ranged from a midpoint value of 0.06 to an upper limit of 0.33.

- The exposure ratio for dioxin ranged from a midpoint value of 0.06 to an upper limit of 0.15.

- Estimates of population health risk indicate no cases of cancer would be expected due to exposure to incinerator emissions.

These results suggest lifetime cancer risks are negligible for individuals and populations living near the incinerator. For effects other than cancer, the incinerator emissions made no significant contribution to everyday exposures. Overall, chemical emissions from the incinerator would not impact adversely, individuals or populations living around the facility. These findings are consistent with other scientific studies which have not predicted adverse health effects from the operation of incinerators.

The health risks of landfilled incinerator ash and the groundwater migration of chemicals in the ash could not be assessed in as great detail as the air emissions. Other studies have indicated that the more hazardous chemicals in bottom ash are unlikely to migrate from a modern landfill, even if the liner fails. Bottom ash and its leachates have not been evaluated for all chemicals, so there may be some chemicals with potential effects, although the possibility appears remote. This could be a topic for consideration in future research.

The landfill

The health impact assessment of air emissions from a landfill followed the same protocols developed for the incinerator assessment. In addition, landfill air emissions were evaluated for the possibility of nuisance odours and cancer risks were estimated for landfill leachate reaching a groundwater drinking supply.

To select priority chemicals for more detailed study, screening was conducted for 68 substances that could be present in air emissions and for 170 in the leachate. Table 2 lists the 18 priority chemicals that were selected.

All the volatile organic chemicals present in the leachate are carcinogens. Other substances, such as iron, zinc and lead, are associated with other significant health effects. Three chemicals are associated with nuisance odours: ethyl mercaptan, methyl mercaptan and hydrogen sulphide.

Exposures were estimated for the chemicals in air, groundwater, soil and backyard garden produce. Vapour movement through soil and basement infiltration were not considered.

The main findings of the health effect assessment for landfill emissions are as follows:

- The combined cancer risk ranges from 4×10^{-6} (1 in 250,000) to 1×10^{-5} (1 in 100,000). None of the individual chemical risks exceeded 1×10^{-5} (1 in 100,000).

- The combined exposure ratios (that is, the ratio of the estimated exposures to published health protection limits) were generally around or below 1.0 for other toxic effects.

- Risks associated with drinking water that may be contaminated by landfill chemicals (e.g., vinyl chloride) were insignificant; i.e. less than 1×10^{-10} (1 in 10 billion). For the reasonable worst case exposures, risks were below 1×10^{-6} (1 in a million).

- Estimates of population health risk suggest no cases of adverse health effects resulting from exposure to the mixture of chlorinated organic chemicals.

- Some exposure ratios above one (1.0) were found for particle-bound iron and odour compounds.

Most of the projected health risks and exposures were well within acceptable levels for most scenarios. Some exposure ratios for particle-bound iron were four to five times over the health protection limit. These are not necessarily significant because the health protection limit includes a margin of safety and the ratios were for extreme exposures that would rarely occur under actual operating conditions. The conclusion is that chemical emissions from landfills are not expected to harm individuals or populations living around the facility.

Complaints about nuisance odours, arising from the release of ethyl mercaptan and methyl mercaptan, could be expected. Sensitive individuals may detect other odorous chemicals. It is not possible to predict fully the extent of odour problems, because these depend on weather patterns dispersing the chemicals through the local community. In addition, certain chemicals may have a stronger odour when present in a mix of other odorous chemicals. Each year, ministry officials receive a number of complaints about landfill odours from people living near these facilities. Studies of landfills outside Ontario also report odour complaints and other subjective symptoms, but do not confirm any adverse health effects.

Conclusions

The health effect assessments predict that incinerators and landfills that are designed and operated as state-of-the-art facilities have negligible effects on human health. Specifically, no adverse health effects (cancer, lung disease, nerve damage or reproductive effects) are likely to occur in a typical community near a modern landfill or incinerator. In certain circumstances, nuisance problems from malodorous compounds may affect some people near a landfill.

2.6 The assessment of effects on the aquatic environment

Both surface water and bottom sediments were evaluated for potential contamination. In the initial assessment, worst-case exposure was assumed for each chemical of concern. Consequently, a calculated exposure that exceeded an aquatic protection limit would identify a potential risk and indicate the need for additional assessment.

Potential aquatic effects from the hypothetical incinerator and landfill were assessed as follows:

- 83 incinerator chemicals and 90 landfill chemicals were identified for assessment;
- exposure concentrations were estimated for the chemicals in surface water and sediments;
- the exposure concentrations were compared to existing aquatic protection limits.

The aquatic protection limits used were: the Provincial Water Quality Guidelines or Objectives, the Provincial Sediment Quality Guidelines, the Canadian Water Quality Guidelines and/or New York State and U.S. EPA wildlife criteria developed for the Great Lakes. These are stringent limits, generally derived using a safety factor of 10 or more. The lowest concentration of a substance capable of producing an adverse effect is determined and the level is then divided by 10 to set the protection limit.

Water quality guidelines were unavailable for some chemicals, so surrogate limits were derived using larger safety factors. An exposure ratio was calculated for each chemical by dividing the predicted concentration in water or sediments by the appropriate guideline. An exposure ratio less than one (1.0) means no aquatic environmental effects are expected.

The incinerator

Chemicals in airborne emissions from an incinerator could reach local surface waters by direct deposition and indirectly by deposition onto land and then runoff into the water body. A mathematical model was used to simulate the air dispersion, deposition and runoff of the chemical emissions.

The surface area of the study site was comprised of 96 per cent land and 4 per cent water. It was assumed that for each chemical, 40 per cent of the deposition onto land would reach the water. Thus, land runoff accounted for 90 per cent of the total chemical input to surface water, with 10 per cent from direct deposition.

The chemical concentration in sediments was assumed to equal the concentration in soils after twenty years of accumulation with no chemical dilution, breakdown or losses. This is a worst case scenario.

The main findings of the assessment of aquatic effect for incinerator emissions are as follows:

For the 83 incinerator chemicals, there were no estimated exceedences of water quality guidelines developed for the protection of aquatic life. For mercury and dioxins/furans there was potential for exceeding the guidelines to protect consumption of sport fish by anglers (mercury) and consumption of fish by wildlife (mercury, dioxins/furans) which depend upon fish for food. A second assessment using more realistic assumptions still indicated some potential to exceed wildlife and sport fish guidelines.

Sediment guidelines were available for 19 chemicals. Chemicals without guidelines were not assessed further. After 20 years of accumulation, sediment concentrations were expected to comply with current guidelines with the exception of manganese. This is apparently due to the higher background concentrations in soil compared with sediment. The projected manganese concentrations are not expected to impair sediment quality.

The landfill

The assessment of the effect of landfill emissions on the aquatic environment considered those chemicals found in air emissions, mobile in soils or often-detected in leachates. Three pathways for inputs to surface water were examined: direct deposition of air emissions, leachate discharges and groundwater discharges.

Deposition to surface water was estimated for dispersed air concentrations of landfill gases. The gases are volatile, so land runoff and sediment accumulation were considered insignificant. Also, a modern landfill would have a stormwater runoff retention pond.

Studies have shown surface water contamination caused by poorly-treated leachate draining from some Ontario landfills. Since the present assessment assumed a modern landfill equipped with pollution controls, the leachate concentrations were lowered by a factor of one thousand. This is a conservative reflection of the contaminant removal provided by on-site treatment and at the municipal sewage plant to which the treated leachate would be pumped.

Reasonable worst case estimates were selected to represent the groundwater concentrations. Chemical breakdown and other losses such as evaporation were assumed to be negligible, except as noted above for leachate. Leachate and groundwater concentrations were reduced by a factor of ten times to calculate surface water concentrations (to account for dilution in the receiving water body).

The main findings of the aquatic impact assessment for landfill emissions are as follows:

- Groundwater discharges resulted in surface water concentrations that did not exceed guidelines.

- After accounting for leachate treatment and dilution, leachate chemicals in surface water were at least one hundred times lower than the guidelines.

- The deposition of air emissions to surface water resulted in water concentrations above the guidelines for four chemicals: 3-methylheptane, nonane, octane and toluene.

The surface water concentrations predicted for 3-methylheptane, nonane, octane and toluene are for a worst-case exposure scenario. These volatile chemicals are not considered persistent and would rapidly evaporate into the air. Realistically, water concentrations are expected to be much lower than the projected levels. In addition, only the guideline for toluene is an established limit. The guidelines for the other three chemicals are surrogates developed using large safety factors. The surrogate guidelines may overestimate aquatic risk since other closely related chemicals have less stringent established guidelines. A second screening approach for these chemicals predicted what the concentrations should be, based on the chemical properties in water. The surface water concentrations estimated in the screening assessment are at least ten times lower than the predictable toxic concentrations. Considering all the evidence, the conclusion is that air emissions of landfill chemicals are unlikely to impair surface water quality.

Conclusions

Most chemical emissions from incinerators and landfills are predicted to have no adverse effects on surface water quality.

Mercury and dioxin emission from incinerators were selected for more detailed assessment due to their potential accumulation in sediment. There is some potential for exceeding the guidelines for the protection of consumption of sport fish by anglers (mercury) and consumption of fish by wildlife which depend upon fish for food (mercury, dioxins/furans), after twenty years of facility operation.

2.7 The assessment of effects on the terrestrial environment

Potential effects on the terrestrial environment from the hypothetical incinerator and landfill were assessed as follows:

- animal and plant species, common to southern Ontario, were selected for study;
- a detailed food pathway model was constructed to estimate chemical exposures for the study species;
- a master list of chemical emissions was screened to develop a short list of priority chemicals;
- the exposures by the study species for the priority chemicals were estimated using the food pathway model;
- the exposures were compared to known toxic or safe exposure levels, or were converted to cancer risk estimates; and,
- potential physical effects were assessed through literature reviews and narrative descriptions.

For practical reasons, several assumptions were necessary to limit the scope of the study. All animal and plant species could not be considered, so representative, “receptor” species were selected for detailed study. Only species common to southern Ontario were selected (most of the province's waste disposal facilities are sited in southern Ontario). While potential effects could be spread over hundreds of years, the study included only the time period when peak effects are likely.

Seven key receptors were selected: plants (grasses and leafy plants), cattle, voles, foxes, hawks, earthworms, and woodcock (a bird species). A detailed food pathway model was constructed: for plants exposed to chemicals by direct contact with air emissions and by uptake from contaminated soil; and for animals exposed by breathing air, drinking water and eating soil, vegetation or other smaller animals.

Earthworms were assumed to be eaten by woodcock in a separate assessment of chemicals persistent in the soil.

Next, a master list of chemical emissions was screened to produce a list of priority chemicals (see Table 3). The priority chemicals were selected by comparing the amounts in emissions and in the environment to: analytical detection limits, air quality guidelines (including human health limits and cancer risks), Ontario loadings or background soil concentrations.

The food pathway model was then used to calculate detailed estimates for the study species and priority chemicals. For most of the chemicals, the exposure estimates were compared to toxic or safe levels in order to calculate an exposure ratio. The toxic or safe levels were determined from a review of the scientific literature. No terrestrial environmental effects are expected for a chemical with an exposure ratio of less than one (1.0).

For a carcinogen, the receptor's exposure (intake) was converted to a lifetime cancer risk using human health risk factors. To assess the overall cancer risk, the risk levels for all the carcinogens were added together. A combined total risk of one in one hundred (1:100) was selected as meaningful for wildlife populations (consistent with an approach used in New York state). While this is higher than acceptable lifetime risk for human health, it was intended for wildlife populations, not for individual people.

Other terrestrial effects were evaluated including: greenhouse gas emissions, habitat loss, acid gases, erosion, drainage and water table effects, dust, noise, litter and pest species. These are discussed in the Technical Report Part D.

Finally, a review was conducted of ministry soil and vegetation surveys and complaint investigations around landfills and incinerators.

Generally, birds received the highest exposures and were the most sensitive study receptors. Mercury was the only substance for which some relevant toxicity data were available for all the study receptors. For the other chemicals, assumptions were made to apply toxicity data to the study receptors. Little is known about the toxicity of such chemicals as 2-methylfluorene and bromodichloromethane, so conclusions about these chemicals are tentative.

The incinerator

The main findings of the assessment of terrestrial effects from incinerator emissions are as follows:

- The exposure ratios and cancer risks were less than the levels of concern, except for mercury from the incinerator.

- The estimated levels of incinerator mercury in the hawk and woodcock suggested there might be possible effect levels for some sensitive bird species (with an exposure ratio 1.56). The estimated amounts of incinerator mercury in hawks was for a worst-case exposure. Actual exposure levels are likely to be lower than the projected levels. Also the terrestrial protection limit assumes that all the mercury is present in the most toxic form. In reality, this is usually only a small portion of the total mercury exposure. Thus significant measurable effects on bird populations are not expected. A more detailed, realistic assessment would be required to better estimate mercury risks to sensitive birds (for example, raptors that prey on small animals, as well as birds that consume soil-dwelling animals such as worms).

- Modern incinerators and landfills with gas collection systems make roughly equal contributions to the greenhouse effect. Incinerators produce carbon dioxide as a major byproduct of combustion. In landfills, lower carbon dioxide production is augmented by methane gas production.

- Incinerators produce more nitrogen oxides, an acid gas, than landfills. A large-scale switch from landfills to incinerators would increase the gas emissions (although this would be a relatively minor source when compared to other sources in Ontario). The concern is that some upland hardwood forests may already be under stress from excess nitrogen oxide loadings and increased amounts may hasten the suspected damage.

The landfill

The main findings of the terrestrial impact assessment for landfill emissions are as follows:

- The exposure ratios and cancer risks were less than the levels of concern.

- For landfill chemicals, the combined total risk of cancer to the hawk was 4:1000. The total combined cancer risk for the landfill chemicals was below the level of concern, set at 1:100.

- Landfills with gas collection systems and modern incinerators make roughly equal contributions to the greenhouse effect. Landfills convert waste to carbon dioxide and also produce methane. Both gases contribute to the greenhouse effect, but methane is a more potent greenhouse gas (21 to 24.5 times more potent than carbon dioxide).

- Landfills occupy and alter more land than do incinerators. Most of this land can be returned to greenspace when the facility closes. Although the ecosystem at a landfill site is less diverse than its original state, the site can provide wildlife habitat and urban parks.

Conclusions

In a review of ministry surveys and complaint investigations, compiled over 20 years, no evidence was found of adverse effects from landfills or incinerators that were well built and well operated. However, adverse effects were found at facilities exhibiting design faults (for example, the lack of gas collection and venting systems), failures in treatment systems, or poor drainage.

Assuming modern, well-run facilities (including collection systems for landfill gases and leachates and advanced pollution controls on incinerators), the chemicals emitted by these facilities are anticipated to pose an insignificant risk of direct adverse effects on terrestrial life forms.

2.8 Risk assessment conclusions

Potential emissions from a hypothetical incinerator and landfill were assessed for their potential effects on human health and the natural environment. Negligible effects are predicted for facilities that meet stringent requirements and standards for design, operation and pollution control. Specifically:

- No significant human health effects (those being cancer, lung disease, nerve damage or reproductive effects) are likely in a typical suburban community located near an incinerator or a landfill. Under certain conditions, nuisance problems linked to malodorous compounds may affect some people close to a landfill.

- An ecological risk assessment predicts that water and sediment quality near an incinerator or landfill will meet Ministry guidelines for the protection of aquatic life.

- Direct or indirect impacts to the terrestrial environment, vegetation or wildlife resulting from incinerator or landfill emissions are not anticipated to be significant. The main differences in terrestrial effects between the two waste disposal methods relate to the amount of land used and to the production of nitrogen oxides.

TABLES

Table 1: Incinerator chemicals assessed in detail for human health risks

Carcinogens:	Other toxic chemicals:
● chromium ● benzene ● cadmium ● vinyl chloride ● arsenic ● dioxin	● nitrogen oxides ● silicon ● hydrogen chloride ● mercury ● sulphur dioxide ● particulate emissions ● iron ● tin ● lead

Table 2: Landfill chemicals selected for detailed health risk assessment

<u>Air emissions</u> Carcinogens: ● benzene ● vinyl chloride ● bromodichloromethane ● 1,1-dichloroethane ● 1,2-dichloroethane ● 1,1-dichloroethylene ● 1,1,2,2-tetrachloroethane ● 1,1,2-trichloroethane ● trichloroethylene ● methylene chloride ● chloroethane	<u>Air emissions</u> (continued) Malodorous chemicals: ● hydrogen sulphide ● ethyl mercaptan ● methyl mercaptan Particle-bound metals: ● iron ● zinc ● lead <u>Leachate emissions</u> Carcinogens: ● vinyl chloride

Table 3: Priority chemicals selected for detailed terrestrial risk assessment	
Incinerator emissions: • benzene • dioxin • mercury • 2-methylfluorene • nitrogen oxides • hydrochloric acid	Landfill emissions • benzene • bromodichloromethane • 1,2-dibromoethane • 1,1-dichloroethane • 1,2-dichloroethane • 1,1-dichloroethylene • hydrogen sulphide • ethyl mercaptan • methyl mercaptan • 1,1,2,2-tetrachloroethane • 1,1,2-trichloroethane • trichloroethylene • vinyl chloride