

Health Prioritization Sub-group Preamble to the NERAM report

This report was prepared by Steve McColl, John Hicks, Lorraine Craig and John Shortreed of the Network for Environmental Risk Assessment and Management (NERAM), for the Health Prioritization Sub-group of the National Framework for Petroleum Refinery Emission Reductions (NFPRER).

The NFPRER, which is being developed through a multi-stakeholder process for the Canadian Council of Ministers of the Environment (CCME), will provide a set of principles and methods to assist jurisdictions to establish annual facility emissions caps for common air pollutants and air toxics from petroleum refineries. The Health Prioritization Sub-group was established to review information on the health implications of petroleum refinery emissions, and to make recommendations for ways to prioritize and phase reductions, to the NFPRER Steering Committee.

This report documents an initial assessment of a variety of schemes for prioritizing air toxics from petroleum refineries by their relative health impact. To do this assessment, NERAM created a series of ranking formulas of differing levels of complexity, corresponding to the various levels in the typology of prioritization schemes of Pennington and colleagues. These formulas were then put into a computer spreadsheet package called HEIDI (Health Effects Indicator Decision Index). To pilot the HEIDI ranking package, it was initially run by inputting data for a limited number of air toxics and refineries, in order to compare the utility of the various prioritization schemes.

The version of HEIDI described in this report is considered a prototype, intended principally to establish 'proof-of-concept'. In a subsequent phase, the NERAM researchers will be extending this work in a number of respects, including by applying the recommended version of HEIDI (level 4c) to a broader range of air toxics and common air pollutants and to the full set of refineries in Canada, and incorporating background levels of air toxics into the modeling. This work is anticipated to provide some detailed, quantitative information for prioritizing substances emitted from Canadian petroleum refineries with respect to relative health risks, to support the Health Prioritization Sub-group in providing advice to the NFPRER Steering Committee on prioritizing reductions.

Assessment of Comparative Human Health Risk-based Prioritization Schemes for Petroleum Refinery Emission Reductions

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FINAL REPORT

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for

CCME National Framework for Petroleum Refinery Emissions

(NFPRER) Health Prioritization Sub-Group

Disclaimer

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Preface

This report describes an assessment of comparative human health risk-based prioritization schemes carried out by the Network for Environmental Risk Assessment and Management (NERAM) under contract to the Canadian Council of Ministers of the Environment (CCME) National Framework for Petroleum Refinery Emission Reductions (NFPRER) Health Prioritization sub-group. The Health Prioritization sub-group, composed of members representing non-governmental organizations, the petroleum industry, provinces and federal government, is one of several sub-groups formed by the CCME to facilitate the development of the National Framework. The National Framework will provide the principles and methods for jurisdictions to establish performance-based facility emissions caps for criteria air pollutants and air toxics from the petroleum refinery industry. The objective of this assessment was to provide a critical evaluation of prioritization schemes to assist the Health Prioritization subgroup in prioritizing reductions of air emissions from petroleum refineries.

The study was initiated in January, 2003 and a draft final report was submitted to the sub-group in March, 2003 for critical review. NERAM would like to acknowledge the Health Prioritization sub-group members, for providing valuable peer review comments on progress reports and the draft final report: Randy Angle, Alberta Environment; Howard Carter, Imperial Oil; Geoffrey Granville, Shell Canada; Therese Hutchinson, Occupational Health Clinic for Ontario Workers in Sarnia; Roger Keefe, Imperial Oil, Barbara MacKinnon, International Centre for Air Quality and Health; Kenneth Maybee, Canadian Lung Association, Ron Newhook, Health Canada; Lynne Patenaude, Environment Canada, Audrey Smargiassi; Régie Régionale de la Santé (Montreal); Andrew Snider, Environment Canada, and Paul Young, Petro-Canada.

The study team made numerous revisions in this final report to address the comments and suggestions provided by the sub-group reviewers. It is noted that two subgroup members commented that a common prioritization approach for air toxics and criteria air contaminants should be possible, while one member indicated that given the differences in duration of exposure and effects it is not possible to compare criteria air contaminants and air toxics based on health criteria for the purposes of prioritization. It is the study team's view that the possibility of prioritizing both air toxics and ambient air pollutants within a single model is very unlikely, particularly within the scope of this study, due to their dissimilar health endpoints and scientific uncertainties in the quantification of adverse impacts of individual criteria air pollutants on human health. NERAM recommends that further research be undertaken to develop and validate a common metric for acute and chronic health impacts, for example by calculating reductions in Quality Adjusted Life Years (QALYS) or Potential Years of Life Lost (PYLL).

Finally, it is noted that for NERAM to undertake the evaluation of various prioritization approaches, it was necessary to develop, outside of the contractual arrangement, a prototype analysis tool, HEIDI – Health Effects Indicators Decision Index. The HEIDI software package is the copyrighted intellectual property of NERAM, and does not constitute part of the deliverables for the CCME contract. The NERAM authors assert

their moral (noncommercial) rights to the copyright of this Final Report and of the HEIDI software.

ACRONYMS and ABBREVIATIONS

ADI	acceptable daily intake
C x T invariance	concentration x time invariance
CBA	cost-benefit analysis
CCME	Canadian Council of Ministers of the Environment
CEPA	Canadian Environmental Protection Act
CNS	central nervous system
COPD	chronic obstructive pulmonary disease
CWS	Canada-wide standards
DC	degraded concentration
DCbg	degraded concentration plus background
EC	emission concentration
ED _n	median effective dose to n % of a population
EI	environmental indicators
EM	emission mass
EP	exposed population
EPA	US Environmental Protection Agency (USEPA)
FC	fate concentration
GIS	geographic information system
GTA	Greater Toronto Area
HAP	hazardous air pollutants
HEAST	Health Effects Assessment Summary Tables (USEPA)
HEC	human equivalent concentration
HEIDI	Health Effects Indicators Decision Index
HRV	health risk values
IE	indicator element
iF	intake fraction
IRIS	Integrated Risk Information System (USEPA)
ISCLT3	Industrial Source Complex Long Term model (USEPA)
ITER	International Toxicity Estimates for Risk

Kow	octanol-water partition coefficient
Kaw	air-water partition coefficient
MB	Mantel-Bryan extrapolation model
MOE	Ontario Ministry of the Environment
MTBE	methyl-t-butyl ether
NERAM	Network for Environmental Risk Assessment and Management
NFRER	National Framework for Refinery Emission Reductions
NO _x	nitrogen oxides
NOEL	No Observed Effect Level
NOAEL	No Observed Adverse Effect Level
NPRI	National Pollutant Release Inventory
OPPT	Office of Pollution Prevention and Technology (USEPA)
PAH	polyaromatic hydrocarbon
PBT criteria	persistence, bioaccumulation and toxicity
PM	particulate matter (including both PM ₁₀ and PM _{2.5})
PM _{2.5}	particulate matter less than 2.5 micrometers in diameter
PM ₁₀	particulate matter less than 10 micrometers in diameter
POPs	persistent organic pollutants
PSL1	Priority Substances List 1
P-T models	persistence - toxicity models
QRA	quantitative risk analysis
REL	reference exposure level
RfC	reference concentration
RfD	reference dose (USEPA)
RP	response parameter
RSEI	Risk-Screening Environmental Indicators Model (USEPA)
SDnb	surrogate dose no background
SO _x	sulphur oxides (including SO ₂ and sulphates)
SP	slope-modifying parameter
T _{1/2}	degradation half life
TC	Tolerable Concentration (Health Canada)
TCDD	dioxin (Tetrachlorodibenzo-p-dioxin)
TDI	Tolerable Daily Intake (Health Canada)

TEPs	toxic equivalency potentials
TEQ	toxic equivalents (for dioxins and furans)
TERA	Toxicology Excellence in Risk Assessment
TRI	Toxic Release Inventory (US)
TW	toxicity weight (USEPA)
UF	uncertainty factors
VOCs	volatile organic compounds
WMPT	Waste Minimization Prioritization Tool (USEPA)
WOE	weight of evidence

GLOSSARY OF TERMS

Abatement	The reduction in degree or intensity of pollutant emissions.
Air toxics	Toxic air pollutants, also known as hazardous air pollutants, are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects.
Atmospheric degradation rate	A fate and exposure measure introduced in Analysis Group 3 through physicochemical parameters and intake fraction.
Bioaccumulation	The process whereby certain toxic substances collect in living tissues, thus posing a substantial hazard to human health or the environment.
Cost benefit analysis	An economic technique applied to public decision-making that attempts to quantify in dollar terms, the advantages (benefits) and disadvantages (costs) association with a particular policy option.
Criteria air pollutants	An air pollutant for which acceptable levels of exposure can be determined and for which an ambient air quality standard has been set. Examples include: ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter.
Crystal Ball	An Excel-based, stand-alone Monte Carlo simulation package used by spreadsheet modelers who need to understand the risks associated with their modeling assumptions.
Degraded concentration	The residual air concentration of each substance calculated as Emission Concentration \times $f(T1/2)$ where $f(T1/2)$ is a function of the degradation half-life of the toxic in air.
Effective concentration	Concentration of a substance that causes a defined magnitude of response in a given system: EC50 is the median concentration that causes 50 % of maximal response.
Effective dose	Dose of a substance that causes a defined magnitude of response in a given system: ED05 is the median dose that causes 5% of maximal response.

Exposed population	Population density distributions for five exposure zones A-E are included in Group 4 and Group 5 analyses based on hypothetical data, approximating a large metropolitan area such as the Greater Toronto Area.
Half life	Time in which the concentration of a substance will be reduced by half, assuming a first order elimination process or radioactive decay.
Harvesting	Refers to air pollution exposures advancing death by only a few days or weeks. It is a factor affecting the interpretation of the response coefficients obtained from daily mortality time-series studies.
Human equivalent concentration	Exposure concentration for humans that has been adjusted for dosimetric differences between experimental animal species and humans to be equivalent to the exposure concentration associated with observed effects in the experimental animal species. If occupational human exposures are used for extrapolation, the human equivalent concentration represents the equivalent human exposure concentration adjusted to a continuous basis.
Inhalation unit risk	The Inhalation Unit Risk is the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 ug/m^3 in air.
Intake fraction	The intake fraction (iF) is the fraction of chemical mass emitted into the environment that eventually passes into a member of the population through inhalation, ingestion, or dermal exposure iF provides a simple, transparent and potentially comprehensive measure of the relationship between emissions and human exposure that incorporates fate, transport, exposure and toxicity.
Linearity	The simplest of toxicological dose-response relationships in which a doubling of the original dose would be expected to results in a doubling of the response frequency, and a halving of the original dose would produce a halving of the response frequency and so on down the dose ladder to zero dose. Used primarily for carcinogen or mutagenic environmental contaminants.
Log(dose) probit distribution	A dose-response model which assumes that each

function	animal has its own threshold dose, below which no response occurs and above which a tumor [or other effect] is produced by exposure to a chemical.
Mantel-Bryan (MB) extrapolation model	The Mantel-Bryan extrapolation is a special case of the conventional log(dose):probit function that describes the dose-response relationship for threshold-acting agents in a population of exposed individuals. It is a means of predicting the probability of a incident health effect for any exposure level (dose) at or below the notional threshold for a given threshold-acting substance. As the notional threshold is typically close to the experimental ED05 level (the exposure level at which no more than 5% of the exposed population is affected), the Mantel-Bryan extrapolation is anchored on the observed ED05 level, with the corresponding slope of the log(dose):probit function assumed conservatively to be equal to one. The actual slope may assume values other than one. Assuming that sufficient dose-response data is available for a given substance, the actual slope may be used in place of the default slope of one. In the HEIDI package, the inclusion of a slope-modifying factor other than one would thus transform the level of analysis from subgroup 4c to subgroup 4d.
Mixing height	The expanse in which the air rises from the earth and mixes with the air above it until it meets air that is equal or warmer in temperature.
Non-threshold toxicity	A class of toxicity mechanisms where the damaging biological processes are thought to occur at any exposure level about zero dose, often in a linear dose-response relationship.
Octanol-water Partition coefficient	The ratio of a chemical's solubility in <i>n</i> -octanol and water at steady state; also expressed as <i>P</i> . The logarithm of <i>P</i> or <i>K</i> (i.e., log <i>P</i> or <i>K</i>) is used as an indication of a chemical's propensity for bioconcentration by aquatic organisms.
PBT criteria	A set of three basic criteria for appraising the likely hazardous properties of environmental contaminants in terms of each substances' Persistence, Bioaccumulation, and inherent (intrinsic) toxicity.
Physicochemical characteristics	Parameters such as atmospheric and non-atmospheric

half-life and intake fraction used to estimate the atmospheric degradation rate of air toxics in Group 3 analyses.

Quantitative risk assessment	The use of science-based risk information and analytical methods to characterize the nature and extent of environmental health risks. Risk assessment employs techniques for measuring and estimating the likely health impacts, and other adverse results of releasing or discharging specified amounts of pollutants. Risk assessment normally includes the risk identification and risk estimation steps, and may in some risk frameworks also include the risk evaluation step.
Reference concentration	An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark concentration, with uncertainty factors generally applied to reflect limitations of the data used. Generally used in EPA's noncancer health assessments.
Reference dose (RfD)	An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used. Generally used in EPA's noncancer health assessments.
Response parameter	Effect measure based on toxicological dose response benchmarks and/or dose-response measures i) in Model 4c the dose-response function has a default slope =1; the Response Parameter for carcinogens is the inhalation unit risk and for non-carcinogens is the ED05 Human Equivalent Concentration and ii) Model 4d the Response Parameter is modified by the slope parameter (for dose-response function where slope \neq 1).

Slope modifying factor	A numerical factor that modifies the default parameter value of the dose-response slope, either for the unit risk function for nonthreshold agents or for the log(dose):response function (Mantel-Bryan extrapolation) for threshold-acting agents. Whenever the parameter value for the Slope Modifying (SP) factor is set at 1 by default, it has no effect on the dose-response slope. When SP values greater than or less than 1 are introduced, this changes the dose-response slope to produce a steeper slope (narrower range of population responses) or a shallower slope (wider range of population responses). By definition, subgroup 4d is the analysis used when the SP has been modified to a value greater than or less than 1. Such SP values should be introduced only on the basis of reliable experimental data obtained from suitable dose-response studies.
Surrogate dose	Starting with the initial release mass, USEPA RSEI models the fate and transport of each chemical through the air and surface water, using each chemical's physicochemical properties and standard exposure models. Then RSEI estimates the surrogate dose using standard exposure assumptions. Background air concentrations are not considered in the exposure assessment.
Tolerable Daily Intake	The total daily intake of a substance occurring over a person's lifetime that should not cause appreciable risk to health on the basis of all known facts. It is usually expressed in milligrams of chemical per kilogram of body weight per day (mg/kg/day). The RfD is calculated in a manner analogous to the TDI.
Threshold toxicity	A class of toxicity mechanisms where disease occurs when underlying biological perturbations exceed a critical level of cell damage or physiological malfunction. Usually applied to environmental substances that are thought not to act by carcinogenic or mutagenic mechanisms.
Toxicity weights	Health effect benchmark under the REIS methodology based on calculation of the USEPA Reference Dose (RfC) value for threshold-acting substances, where $TW = 1/RfC$. Also used indirectly (for comparative purposes) to derive a corresponding Health Canada

toxicity benchmark based on the Health Canada Tolerable Concentration (TC) value, where $TW = 1/TC$.

Type A uncertainty	Arise from the inherent unpredictability of complex processes that occur in nature. No amount of additional data collection or analysis can reduce the degree of variability found in natural processes.
Type B uncertainty	uncertainties (i.e. model uncertainty, parameter uncertainty and decision-rule uncertainty) that are reducible by gathering and analyzing additional scientific data.
Uncertainty factors (replaces the older term Safety factors)	One of several, generally 10-fold factors, used in operationally deriving the RfD and RfC from experimental data. UFs are intended to account for (1) the variation in sensitivity among the members of the human population, i.e., interhuman or intraspecies variability; (2) the uncertainty in extrapolating animal data to humans, i.e., interspecies variability; (3) the uncertainty in extrapolating from data obtained in a study with less-than-lifetime exposure to lifetime exposure, i.e., extrapolating from subchronic to chronic exposure; (4) the uncertainty in extrapolating from a LOAEL rather than from a NOAEL; and (5) the uncertainty associated with extrapolation from animal data when the data base is incomplete.
Unit risk	A measure of the health risk association with a continuous daily exposure to a pre-defined dose of a toxic substance, usually a carcinogenic agent. For example, for a hypothetical carcinogen, the Unit Risk for continuous exposure to 1 milligram/kilogram body weight per day might result sin a lifetime cancer risk of 5×10^{-5} (i.e. 5 in 10,000; 1 in 20,000).
Weight of evidence	Considerations involved in assessing the reliability of available information about hazard; and the quality of testing methods, the size and power of the study design, the consistency of results across studies, and the biological plausibility of exposure-response relationships and statistical associations.

Sources

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EXECUTIVE SUMMARY

An assessment of comparative human health risk-based prioritization schemes for Canadian petroleum refinery emission reductions was undertaken by the Network for Environmental Risk Assessment and Management (NERAM) for the CCME National Framework for Petroleum Refinery Emission Reductions (NFPRER) health prioritization sub-group. The overall objective of the project was to “*carry out an assessment of human health risk-based prioritization schemes that may be useful for priority-setting for refinery emission reductions*”. Based on a review of literature, 14 issues were identified for consideration in the evaluation of alternative priority screening methods. These issues addressed uncertainties in relating emissions (from various pathways) to human exposures; limited scientific understanding of short and long term health effects associated with acute and chronic exposures; limited monitoring data to characterize background concentrations, the need for approaches which consider threshold and non-threshold acting substances, air toxics and criteria air pollutants; and the data and resource requirements to both carry out and validate the prioritization approach.

Following the review of literature and assessment of existing prioritization methods, NERAM determined that to carry out the study, it was necessary to develop a prototype analysis tool (HEIDI – Health Effects Indicators Decision Index) outside of the contractual arrangements. HEIDI offered a number of capabilities not available in existing prioritization tools: i) the capability to incorporate physicochemical parameters, toxicological dose-response parameters, population density functions, and background air concentrations for a variety of air toxics; ii) the capability to assess priority setting methods of varying complexity and assess the sensitivity of various input parameters; iii) the capability to extend the analysis of emission reduction priorities to all Canadian refineries and all NPRI emissions, and; iv) the capability for model validation and groundtruthing.

The study approach was based primarily on the typology for priority setting approaches developed by Pennington and Bare (2001). Five levels of prioritization ranking schemes were identified according to increasing comprehensiveness of model inputs and increasing complexity of analyses as follows:

- Analysis Group 1: ranking by total emissions mass only (direct data summation)
- Analysis Group 2: ranking by emissions mass with toxicity weightings (effect normalization)
- Analysis Group 3: ranking by emissions mass with toxicity weightings, and physicochemical characteristics (criteria-based score and ranking)
- Analysis Group 4: ranking by emission mass, toxicity weighting, physicochemical characteristics, and exposed population (model-based approaches)
- Analysis Group 5: model-based exposure assessment and quantitative dose-response assessment (full risk assessment)

According to conventional risk assessment frameworks, the first three levels of analysis should be considered a type of hazard assessment, since the input parameters focus exclusively on the inherent characteristics of the chemical agent and lack site-specific information such as exposed population distributions. The fourth and fifth levels represent quantitative risk assessment models because they estimate the probable incidence of health effects in exposed human populations, based on a defined dose-response relationship.

The basic concepts of the Analysis Groups 1 to 4 (Group 5 cannot be modeled using generic ranking formulas) were operationalized using algebraic formulas within a prototype computer spreadsheet package called HEIDI for the purpose of comparing the priority rankings produced by each of the four Analysis Groups, including several sub-analyses. The spreadsheet package includes a series of standardized datasets that supply the ranking formulas with the required physicochemical and toxicological parameters for each air toxic substance, and the NPRI annual emission inventory data for various petroleum refineries in Canada.

As a prototype prioritization ranking system, the HEIDI spreadsheet package contains a number of simplifying parametric and modeling assumptions:

- Air dispersion modeling: It was assumed that the exposed population was located within a series of five concentric cylindrical zones (Zone A to Zone E) centered on a single point source release of the NPRI refinery emissions inventory under examination. The outer radius of the concentric Zones A to E were predefined at distances of 1, 2.5, 5, 10 and 25 km from the emission centre. For most of the analysis groups (except subgroup 4a), the calculation of air concentration was assumed to follow the simple air dispersion of a classical ‘well-mixed compartment’.
- Intra-class dose-response independence: It was assumed that there was no intra-class interaction between agents with similar chemical and toxicological properties. The assessment of the dose-response function for the six air toxics was relatively simple because they were selected to represent different classes of toxicants that possessed dissimilar mechanisms of action. For threshold-acting agents it is often seen as inappropriate to assess the dose-response function of similar toxicants as if each were totally independent
- Low dose extrapolation: For the estimation of case incidence rates in Group 4 analysis, it has been assumed that a suitable low-dose extrapolation function can adequately model expected health impacts by using a simple monotonic dose-response function.
- Dose-rate effects: It has been assumed that chronic risk estimates can be calculated independent of any dose-rate effects and short-term peaks of exposure. This assumption would probably NOT hold for many acute-acting criteria air pollutants, such as ozone or PM_{2.5}.
- Homogeneous population: It has been assumed that the exposed population is relatively homogeneous with respect to individual susceptibility toward the chronic health effects of exposure to air toxics. An exposed population distribution that

approximates the Greater Toronto area is assumed for all three refineries as well as the hypothetical worst-case refinery.

To establish proof of concept by evaluating the relative strengths and weaknesses of each of the Analysis Groups, six substances were selected for ranking analysis based on their importance and their representativeness as various classes of chemical toxicants (carcinogens, metals, VOCs etc). The six air toxics assessed were benzene, MTBE, mercury, n-hexane, toluene and ethylbenzene. The NPRI emissions datasets for were assessed for the Shell Scotford Refinery in Fort Saskatchewan Alberta, the Chevron Refinery in Burnaby BC, and the Irving Oil refinery in Saint John NB, plus a hypothetical worst-case refinery.

The results of the analysis indicated the following:

- Overall changes in the priority ranking for the six air toxics according to analysis subgroup varied moderately, and in some cases not at all, for the three refineries that were evaluated. However, the subgroup ranking varied much more widely in the hypothetical worst-case refinery suggesting that the limited degree of rank shifting may reflect the predominance of mass emissions of a few major releases characteristic of each facility. The relative insensitivity of shifts in ranking order by subgroup may be due to the limited number of air toxic substances evaluated or due to the absence of site-specific background air concentration data for input into the Group 4 analysis.
- The top three rankings tended to vary more in their rank ordering than the lower rankings. The observed pattern of ranking shifts between analysis subgroups appears to support the conclusion that careful consideration of data inputs and ranking formulas is an important area for further study.
- The analysis of the four prioritization approaches indicated that the preferred base model for determining the rank-order for prioritization of NPRI refinery emissions based on health effects is analysis subgroup 4c. This approach accounts for the expected background concentration for each substance, and relies on two types of dose-response formula which are both a continuous function of exposure (dose) applicable across any possible range of exposure concentrations – at all exposure levels for substances not exhibiting a threshold; and below, near, or above the threshold levels for threshold-acting agents. The use of continuous linear functions for both non-threshold and threshold-acting agents ensures that the estimated population incidence of health effects is founded on sound toxicological theory.
- Analysis subgroup 4d, a further elaboration of subgroup 4c which allows for the inclusions of slope-modifying parameters for the dose-response function should be considered, for the time being, as a possible future refinement of Group 4c. Data may or may not currently be available to more reliably reflect the relationship of exposure and response under specific conditions.

An analysis of priorities for refinery emission reductions among criteria pollutants was assessed by applying site specific modeling (Analysis Group 4 and 5) to the hypothetical worst-case refinery. At this proof of concept stage in the development of HEIDI, it was

not considered within the scope of the project to assess the capability of a common tool for prioritizing among air toxics and criteria air pollutants. The possibility of prioritizing both air toxics and ambient air pollutants within a single model such as HEIDI is tempting, but very unlikely given our present state of knowledge. The air toxics are based on chronic (365 day) predicted health effects (often irreversible, such as cancer) whereas the ambient air pollutants are based mainly on acute reversible (e.g. 1, 8, 24 hour) health effects. Creating a common priority ranking for dissimilar health endpoints is likely to be meaningless for priority setting.

The intention of applying site specific modeling is to identify those ambient air pollutant emissions of greatest concern to human health when dispersion, photochemical removal, gravitational disposition, and population geography are included in the assessment. The USEPA regulatory model, Industrial Source Complex Short Term model (ISCST3) has been widely applied to model air emissions from point, area, and volume sources in generally flat terrain and is deemed suitable for all Canadian refineries assuming that the primary population and terrain impacts are within a regular terrain within a few kilometers of the facilities.

For this hypothetical worst-case study, the maximum value of emissions recorded for carbon monoxide, nitrogen oxides, sulphur oxides, PM_{2.5}, PM₁₀ and VOCs were extracted from data provided by Environment Canada. Ozone was not included because it is considered a pollutant of secondary origin. The facility was assumed to exist in a real refinery location in southern Ontario and emissions were assumed to be emitted at a constant rate from a point source location in the centre of the refinery property over a period of one year. A real meteorological dataset recorded at a US airport that borders southern Ontario was used. The dispersion model was set to provide data for three different averaging times: 1 hour, 24 hour, and one year. As part of the geographical site-specific analysis, the population and residential dwelling were estimated in the region around the refinery.

The model estimates show the possibility of several exceedances of Canadian or Ontario air quality standards. Sulphur dioxide concentrations exceed MOE criteria for several kilometers around the worst case refinery. Nitrogen dioxide concentrations exceed MOE criteria for approximately 1 km around the refinery. PM_{2.5} (primary emission) concentrations exceed CCME Canada-wide standards in the 1 kilometer radius around the refinery. It is important to note that modeled estimates of the pollutant concentrations do not include background concentrations. MOE measurements of background concentrations in the extended site of the worst case refinery suggest that they are comparable to the estimates of emissions from the refinery and may pose a significant risk. Estimates of the upper bound of secondary particulate formation from primary particulate, sulphur dioxide, and nitrogen dioxide suggest that in worst possible case conditions the worst case refinery may contribute a considerable additional secondary particulate burden to the airshed.

It is recommended that the application of the HEIDI prioritization tool be expanded to include all NPRI substances for all refineries across Canada. It is important to note that

the priority outcomes depend to a great extent on value judgments and model assumptions, which are decisions that must be made by the NFPRER health prioritization subgroup. It is recommended that the NFPRER health prioritization subgroup examine the impacts of values (e.g. the choice of uncertainty factors) and model assumptions (e.g. various approaches to considering background levels) on ranking outcomes. Further steps to refine the prioritization tool include: i) provision for computation of the estimated risk reduction for a given emission reduction; ii) uncertainty analysis on key variables using Monte Carlo simulation techniques; iii) data-driven refinement of the model using Canadian air modeling datasets, inclusion of real population distribution profiles, site specific background pollutant concentrations, windrow and seasonal climatic effects, routine inclusion of ISC air model for transport and fate modeling, and inclusion of a slope modifying factor; iv) comparison of HEIDI model predictions with site-specific quantitative risk estimation studies; v) further investigation of fundamental methodological issues including: assessment of multiple exposures, development of rank-ordering system for precursors of key secondary criteria air pollutants, construction of a common risk metric for air toxics and criteria air pollutants such as reduction in Quality Adjusted Life Years (QALY-lost) or Potential Years of Life Lost (PYLL), and refinement of ED05 calibration based on primary dose-response data for threshold-acting substances. Policy issues to be explored for acceptance and successful implementation of the prioritization approach include: consensus processes (stakeholder and peer review) for selection of the most appropriate analysis subgroup for priority ranking; assessment of the cost and competitiveness implications for the refinery sector in Canada; and methods for economic analysis of alternative risk control strategies.