Health Effects Indicator Decision Index (HEIDI): A risk-based tool for ranking abatement of air pollution release inventories by expected regional health effects

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AIRNET
A Thematic Network on Air Pollution and Health

NERAM
Network *for* Environmental Risk Assessment *and* Management

Policy Background

The Canadian Council of Ministers of the Environment (CCME) is responsible for devising Canada wide standards for major air pollutants such as PM2.5 and ozone, developing control programs for vehicular air emissions, and defining emission reduction strategies for various industrial sectors. The CCME under the *National Framework for Petroleum Refinery Emissions Reductions* (NFPRER) is currently developing an emissions reduction strategy for the petroleum refinery sector *(ref.1)*.

Environment Canada currently collects annual emissions reports on over 200 chemical substances, mixtures, and precursors from all 23 refineries in Canada as part of the *National Pollutant Release Inventory* (NPRI). In setting priorities for abatement. air emissions must be ranked according to their toxicity-weighted health effects, not merely by their emissions mass. Risk-specific environmental indicators (RSEI) consist of toxicity weightings (TW), plus other parameters such as exposed population (EP) and environmental persistence. Various analysis groups are defined according to how these parameters are organized and used to calculate health risk.

Ranking of Emission Reductions

The *Health Effects Indicator Decision Index* (HEIDI) is a risk analysis tool developed by NERAM as part of the NFPRER initiative. It performs a spreadsheet analysis in MS EXCEL to determine the relative weighted health effects of a given set of NPRI substances emitted within a specified refinery site. This tool allows decision-makers to view the priority rankings for air emissions reduction by their toxicity weightings and other RSEI parameters. The priority rankings are displayed for Analysis Groups 1 to 4, including several types of subanalysis within each Group (*ref. 2*). The HEIDI ranking method has several useful capabilities:

- determines the priority rankings in each refinery for reducing NPRI emissions, according to analysis subgroup
- estimates the effects of regional population distribution profiles and varying atmospheric mixing heights
- provides a 'what-if' scenario analysis in a given refinery to determine the degree of emission reduction required to shift downward the ranking of a specified air toxic
- examines the effect of differences in TW values for air toxics for various jurisdictions (USEPA vs Health Canada), which can produce significant shifts in rankings

HEIDI uses continuous linearized dose-response functions in analysis subgroups 4c and 4d to characterize the TW for threshold-acting agents. This eliminates the computational artifacts of step-function TW parameters such as Reference Concentration (RfC) or Tolerable Concentration (TC).

Findings and Conclusions

Rankings for air emission reductions in oil refineries are sensitive to assigned TW values and other RSEI parameters.

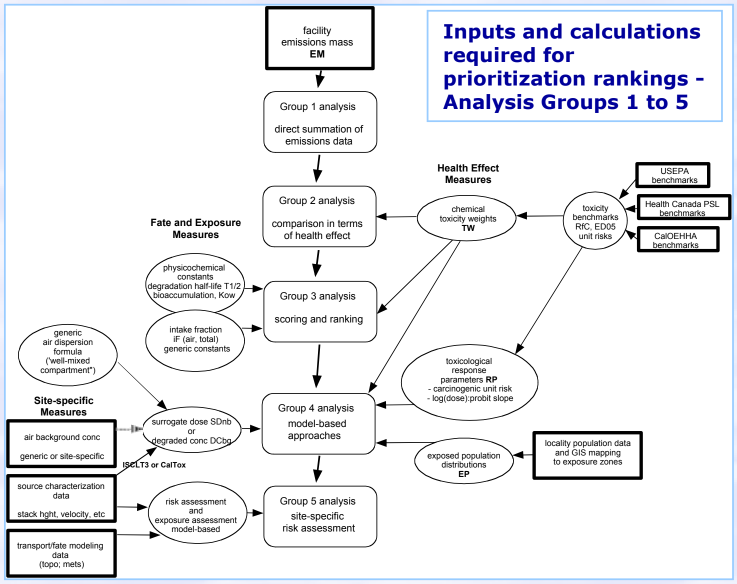
Differences in TW values in separate jurisdictions (USEPA vs Health Canada) can produce significant shifts in rankings.

Priority outcomes are greatly affected by selective inclusion of RSEI input parameters and risk model assumptions.

Analysis subgroup 4c is the recommended ranking method.

The observed pattern of ranking shifts between various analysis subgroups supports the conclusion that careful consideration of parameter inputs and ranking formulas is important enough to engage in further methodology studies.

Inputs and calculations required for prioritization rankings - Analysis Groups 1 to 5



CCME Prioritization project
Analysis Guide

Analysis Group	Sub group	calculation of Indicator Element (IE)	emission: emission mass EM = tonnes*1000 [kg]	emission: emission concentration EC = EM*1/V; V_{dil} = pi*r^2*h	estimated dose: degraded concentration DC = EC *f(1/$T_{1/2}$)	estimated dose: fate concentration FC=EC*iF; intake fraction iF (air, total)	estimated dose: surrogate dose SD_{nb} no background	estimated dose: degraded concentration plus background =DC_{bg}+bg	measure of toxicity: toxicity benchmark RfC	measure of toxicity: toxicity weight TW	measure of toxicity: response parameter RP	persons at risk: slope-modifying parameter SP	persons at risk: exposed population EP
1		EM	+	-	-	-	-	-	-	-	-	-	-
2	a	EC x RfC	-	+	-	-	-	-	+	-	-	-	-
	b	EC x TW	-	+	-	-	-	-	-	+	-	-	-
3	a	DC x TW	-	-	+	-	-	-	-	+	-	-	-
	b	FC x TW	-	-	-	+	-	-	-	+	-	-	-
4	a#	SDnb x TW x EP	-	-	-	-	+*	-	-	+	-	-	+
	b¤	DCbg x TW x EP	-	-	-	-	-	+**	-	+	-	-	+
	c¦	DCbg x f(RP) x EP	-	-	-	-	-	+**	-	-	+	-	+
	d	DCbg x f(RP, SP) x EP	-	-	-	-	-	+**	-	-	+	+	+
5		full risk assessment model	+	+	+	+	+/-	+*	+	-	+	+/-	+

USEPA REIS formula for IE
¤ Health Canada PSL formula for IE
¦ Response Parameter formula for IE (dose-response function with default slope = 1)
Response Parameter formula for IE modified by Slope Parameter (for dose-response function where slope - 1)
*site-specific ISCLT model (or similar transport and fate air model)
** generic well-mixed compartment formula, or site-specific ISCLT model

HEIDI Health Effects Indicator Decision Index version 1.3

Stephen McColl and John Hicks are the authors of this work

NERAM Refinery Prioritization project for CCME (air toxics)
front end interface sheet

4	ENTER FACILITY SELECTION	ENTER MIXING HEIGHT (KM)	1.5	default mixing height = 1.5 km

1= AB Scotford
2= NB St John
3=BC Burnaby
4= hypothetical worst-case refinery

100% = no reduction in current emission levels
10% = reduction to 10% of current emission levels

RESIDUAL EMISSIONS TARGET indicates what is the target level of continuing emissions after abatement

hypothetical worst-case refinery **ENTER RESIDUAL EMISSIONS TARGET (1% to 100% of current level)**

formula	Analysis Group	subgroup	mercury (100)	MTBE (100)	ethylbenzene (100)	benzene (100)	toluene (100)	n-hexane (100)
EM	1	1	6	1	5	3	2	4
EC x 1/RfC	2	2a	5	2	4	1	6	3
EC x TW		2b	6	4	5	1	3	2
DC x TW	3	3a	4	6	3	1	5	2
FC x TW		3b	2	6	4	1	5	3
SDnb x TW x EP	4	4a	4	6	3	1	5	2
DCbg x TW x EP		4b	4	6	3	1	5	2
DCbg x f(RP) x EP		4c	4	2	6	1	5	3
DCbg x f(RP, SP) x EP		4d	4	2	6	1	5	3

NOTE: the decision index is currently configured for an exposed population distribution (EP) that approximates the Greater Toronto area for this reason, the scenario reflects only what would occur hypothetically for the 3 refinery facilities if they were located in the western GTA

valid index results will only be produced when accurate site-specific **population distribution values are provided by a GIS population databa**
valid index results will only be produced when accurate site-specific **background air toxics concentrations are provided by a monitoring dat**

(1) Assessment of comparative human health risk-based prioritization schemes for petroleum refinery emissions reduction. NERAM Report to CCME. May 26, 2003.

(2) Pennington, DW & Bare, JC. (2001). Comparison of chemical screening and ranking approaches: The waste minimization prioritization tool versus toxic equivalency potentials. Risk Analysis, vol. 21, No. 5, 897-912.

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