Development of a Health Effects-based Priority Ranking System for Air Emissions Reductions from Oil Refineries in Canada

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Background

In Canada, the National Air Issues Coordinating Committee (NAICC) is currently engaged in a process to determine how best to reduce air emissions from oil refineries. The NFPRER (National Framework for Petroleum Refinery Emission Reduction) is being developed with the input of stakeholders including industry, NGOs, and regulatory jurisdictions. One component of this framework is the development of a tool to help prioritize air emissions for reduction based on estimated health impacts.

HEIDI II: Health Effects Indicators Decision Index

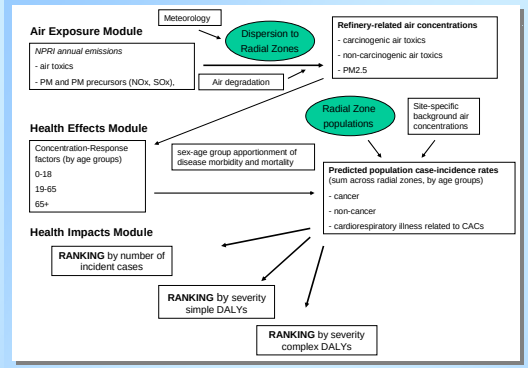
HEIDI II is an Excel spreadsheet-based model that prioritizes a series of air toxics and criteria air contaminants commonly emitted from Canadian oil refineries. It was developed according to the fundamental concepts of a Level 4 LCIA (life cycle impact analysis) as described by Pennington and Bare (2001).

Model Input Parameters

- Users select the refinery of interest from the Inputs sheet:

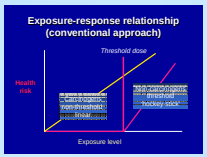
- HEIDI II also incorporates several software switches that allow variation of model input parameters such as
  - stack height (metres)
  - average daily sunlight hours (for calculating photodegradation).
  - If a refinery reports emissions of zero for any chemicals, the user may opt to specify a percent of regulatory reporting thresholds as input in place of notional zero (below reporting threshold) values.

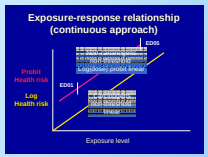
HEIDI II: Modular Structure



Modelling Dose-Response in HEIDI II

- HEIDI II uses a linear non-threshold approach to model dose-response for carcinogens and criteria air contaminants (CACs)
- A linearized transform of log dose:probit approach was used to model dose-response for substances that may exhibit threshold-type behaviour.





Substances that are included in HEIDI II

- Selected by a group of stakeholders including industry, Health Canada (government), and NGOs

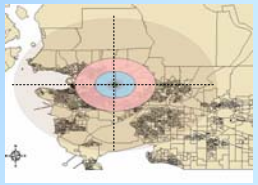
Modelled as Carcinogens (linear, non-threshold dose-response)	Modelled as Non-carcinogens (log dose: probit dose-response)	CACs (Criteria Air Contaminants) (linear, non-threshold dose-response)
1,3-Butadiene Benzene Ethylene (as oxide) Nickel (and its compounds) PAH (as benzo(a)pyrene)	1,2,4-Trimethylbenzene Anthracene (Total) BTEX (Benzene, Toluene, Ethylbenzene, Xylene) Cyclohexane Dicyclopentadiene Diethanolamine (and its salts) Ethylene Hydrogen sulphide Isoprene Mercury (and its compounds) Methanol Methyl ethyl ketone Methyl isobutyl ketone Methyl tert-butyl ether Naphthalene n-Hexane Phenol Propylene Styrene Sulphuric acid Vanadium and its compounds Zinc (and its compounds)	Secondary PM2.5 from sulfur oxides (NH4)2SO4 Secondary PM2.5 from nitrogen oxides (NH4)NO3 Primary PM2.5

Geographical Exposure Mapping

20 "Zones" were defined around each refinery. These were delineated by circular radii at 1, 2.5, 5, 10, and 25 km from the centre of the refinery site, divided into northeast, southeast, southwest, and northwest quadrants. In each zone, the following were determined:

- Predicted concentration of each emitted chemical according to air dispersion model
- Population of youth (0-19 years), adults (20-59 years), and seniors (60+ years)
- Predicted case incidence of disease associated with each emitted chemical

Predicted incidence can be summed across zones to calculate total predicted incidence in the region of the refinery resulting from each of its air emissions



Identification of 20 quadrants /zones surrounding the Chevron Refinery in Vancouver, British Columbia, Canada

Model Output

HEIDI II ranks substances emitted from each refinery in order of greatest predicted impact on human health, using one of three different methods:

- **Ranking by Predicted Incidence**
- **Ranking by Predicted Simple DALYs** (Disability Adjusted Life Years)
- **Ranking by Predicted Complex DALYs**

Using the DALY approach, priority rankings can be calculated within each of the three chemical classes, or across all three classes together.

← **Sample Output**

Data Sources

- Annual reported emissions: Environment Canada's NPRI (National Pollutant Release Inventory) for Canada's 20 active oil refineries
- Air dispersion: using a generic ISC3/AERMOD approach
- Photodegradation rates: SRC (Syracuse Research Corporation) database
- Ambient background levels of each substance: Environment Canada monitors
- Toxicity parameters for each substance for children, adults and seniors: Health Canada, EPA, CalEPA
- Population living in areas surrounding refinery: Canada Census data at dissemination area level (smallest geographical census subdivisions available)

Future Research

- Further testing and validation
- Incorporating uncertainty analysis
- Sensitivity and importance analysis
- Examine implications of predictions for each refinery site
- Perform "what if" scenario analysis for priority exposure reductions (i.e how much % reduction required to move a substance down by one ranking level)

References

Pennington, D.W., and Bare, J.C. (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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To obtain the HEIDI II model program, user's guide and technical report, please visit www.irr-neram.ca