

## Health Prioritization Sub-group Preamble to the WBK report

This report was prepared by WBK and Associates Inc. 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 WBK report reviews recent public health risk assessments conducted in the area of impact of petroleum refineries, and epidemiological or community health studies of populations residing in the vicinity of petroleum refineries. This focus was intended to access information on possible health impacts that is specific to petroleum refineries, while enabling the work to be completed within the time and funds that were available.

The database of studies specific to petroleum refineries is difficult to interpret, because of the small number of studies, shortcomings in study design, concomitant exposure to other industrial sources and/or somewhat inconsistent findings. In spite of these limitations, WBK reported that the public health risk assessments reviewed identified possible concerns for short-term respiratory effects from exposure to sulphur dioxide and other substances, and for cancer risks from benzene and other substances, near some of the Canadian refineries. The WBK report noted these risk assessments were designed to be conservative (ie. precautionary) in nature. The Health Prioritization Sub-group notes that there was also some very limited support for these findings in the epidemiology studies of populations near petroleum refineries, though the evidence from these studies was inconclusive (somewhat inconsistent, exposures inadequately characterized, relative contribution of the refinery to local Air Quality not determined).

The Health Prioritization Sub-group also noted that the work by WBK complements, and provides some additional support for the well-documented cardiac and respiratory effects of air pollution including PM and ground-level ozone (pollutants which result from emissions from numerous sources including petroleum refineries). This extensive literature is presented in the Science Assessment Documents for respirable PM and ground-level ozone and the Priority Substances List assessment report for respirable PM ( [www.hc-sc.gc.ca/hecs-sesc/air\\_quality/science.htm](http://www.hc-sc.gc.ca/hecs-sesc/air_quality/science.htm), [www.ec.gc.ca/substances/ese/eng/psap/final/pm-10.cfm](http://www.ec.gc.ca/substances/ese/eng/psap/final/pm-10.cfm) ), and has recently been summarized and updated in the "Update in Support of the Canada-wide Standards for Particulate Matter and Ozone" reports [www.ccme.ca/initiatives/standards.html](http://www.ccme.ca/initiatives/standards.html).

Information contained in these sources, as well as in this WBK report, was considered by the Health Prioritization Sub-group in developing their advice to the NFPRER

Steering Committee concerning the health implications of petroleum refinery emissions and their recommendations for prioritizing reductions.

The WBK report also illuminates areas of data limitation that might be considered by the NFPREER initiative. Improving the monitoring, recording and reporting of emissions could improve the information that is necessary to assess the health impacts that could be attributed to refinery emissions. The Health Prioritization Sub-group will advise the Steering Committee on data issues that might be addressed in the methodology, the monitoring and reporting components of the National Framework for Petroleum Refinery Emissions Reductions.

**HEALTH IMPLICATIONS OF  
PETROLEUM REFINERY AIR EMISSIONS:**

**PART I  
MAIN REPORT**

**FINAL**

**Prepared for  
Canadian Council of Ministers of the Environment (CCME)**

**By  
WBK & Associates Inc.**

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## **Disclaimer**

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## EXECUTIVE SUMMARY

An assessment of information available in the literature on health implications of air emissions from petroleum refineries was undertaken for the National Framework for Petroleum Refinery Emission Reduction Health Prioritization Sub-group. Electronic databases at the University of Alberta and University of Calgary library systems were searched and contact with several agencies and refinery industry people was made as part of the review. The review was restricted to identification of original research and reports published in English between 1990 and 2003.

Four human health risk/impact assessments and twenty epidemiological publications about health implications of petroleum refinery air emissions were identified and discussed in this report. Numerous citations about published research of occupational exposures in the petroleum refinery industry were identified. These citations are provided in a report under separate cover.

The review did not include epidemiological literature on health effects arising from exposure to particulate matter (PM) and ozone, although petroleum refineries are among numerous sources that contribute to these air pollutants. Many studies have linked respiratory and other health effects to these air pollutants. The Canada-wide Standards for PM and ozone are based on these types health effects, as presented in the science assessment documents for the National Ambient Air Quality Objectives for Particulate Matter and Ozone as published by the CEPA/FPAC Working Group on Air Quality Objectives and Guidelines.

Rather than reviewing that literature, it was decided to limit this review to public health risk assessments conducted in the area of impact of petroleum refineries, and epidemiological or community health studies of populations residing in the vicinity of petroleum refineries. This approach was intended to provide access to information on possible health impacts that is specific to petroleum refineries, while enabling the work to be completed within the available time and funds.

### **Human Health Risk/Impact Assessment Review**

The risk assessments defined health outcomes in terms of potential acute or chronic health risks, depending on length of exposure and mode of chemical action. Of the four health risk/impact assessments reviewed, individual air pollutants of concern were estimated to exceed acute exposure criteria for two petroleum refineries. These air pollutants included sulphur dioxide (at the two refineries); and particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>), ozone, acid aerosols and nitrogen dioxide at one of the refineries. Air monitoring data in the vicinity of this refinery also indicated incidents of ambient levels being above existing air quality criteria for selected air pollutants.

Three of the risk assessments predicted incremental lifetime cancer risk values associated with benzene exposure at or above a background incremental lifetime cancer risk level of one in 100,000. Based on ambient air concentrations, one petroleum refinery risk assessment indicated chronic exposures to a butadiene group, aldehyde group and benzo(a)pyrene group of chemicals resulted in predicted incremental lifetime cancer risk values greater than one in 100,000. However, because of the conservative nature in which the risk calculations were performed, authors of these assessments concluded that no chronic health risks could be attributable to petroleum refinery air emissions.

In the context of this review, a limitation to interpreting the results of these assessments is that some of them were intended to assist with refinery expansion regulatory approvals. In numerous instances assumptions of exposure factors were made that err on the side of public safety in order to exaggerate exposure and risk estimates, as is common practice in these assessments. This speaks to the conservative nature in which risk calculations were performed. Results of these assessments should be used with caution to infer representative health effects in a community as a result of exposure to petroleum refinery air emissions. The context of emphasizing high-end (exaggerated) population exposures and risk estimates does not reflect the true complexities of risk situations. The proper context of risks posed to an overall population considers risks that are broadly reflective of real-life risk situations, not only high-end (exaggerated) risks.

## **Epidemiology Review**

Eight published epidemiological/community health investigations of cause-specific mortality associated with residence in proximity to industrial areas containing oil refineries and/or urban areas with oil refineries were reviewed:

- Four investigations reported no associations with different cause-specific mortality and residence.
- Two investigations of the same study area reported a slight increase in risk of lung cancer death.
- One investigation reported an increase in cancer death rates
- one investigation reported both “no association” and an “association” with different cause-specific mortality.

Seven published epidemiological/community health investigations of cancer incidence associated with residence in proximity to industrial areas containing oil refineries and/or urban areas with oil refineries were reviewed:

- Four investigations reported associations with specific cancers and residence however the findings of two of these were not statistically significant.
- Two investigations reported both “no association” and an “association” with specific cancers and residence.
- One investigation reported no associations with specific cancers and residence.

Three published epidemiological/community health investigations of pregnancy outcomes associated with residence in a Taiwanese municipality with petrochemical facilities were reviewed:

- One investigation reported elevations in the male:female birth ratio.
- One investigation reported a slight increase in the risk of preterm delivery.
- One investigation reported an increase in the risk of low birth weight delivery at term however the findings were not statistically significant.

Two published epidemiological/community health investigations of respiratory health associated with residence in Taiwanese municipality with petrochemical facilities were reviewed:

- One investigation reported a higher prevalence of wheezing, cough, upper respiratory symptoms, bronchitis, asthma.
- The other investigation reported a higher prevalence of cough, wheezing, bronchitis, throat irritation, phlegm production, eye irritation, nausea.

Two published epidemiological/community health investigations of odour perception and annoyance associated with residence in proximity to an oil refinery were reviewed. Both investigations reported no association with prevalence of odour perception and annoyance and residence.

The majority of epidemiological/community health investigations reviewed have used ecological designs. These designs involve units of analysis at the aggregate level (populations or groups of people), rather than individuals and they cannot link exposures with outcomes at the individual level. Associations observed at the aggregate level may not represent associations that exist at the individual level. In the context of assisting the Health Prioritization Sub-group in understanding possible health implications associated with exposure to petroleum refinery air emissions, the following recommendation is made to address an existing data gap:

- The use of proxy measures and of ambient air measures limits the assessment of the contribution of petroleum refineries to the total air pollution in a study area. Refinery source emission–ambient air measurement reconciliation (source apportionment) can be undertaken in study areas adjacent to refineries to provide valuable information on the contribution of petroleum refinery emissions to the total air pollution in these study areas.

### **Concluding Remarks**

The following concluding statements are made based upon the collective review and assessment of four health risk/impact assessments and 20 epidemiological/community health investigations of petroleum refinery air emissions:

- The human health risk/impact assessment studies examined substances that are reported to cause cancer and substances that are reported to contribute to short-term respiratory effects (respiratory symptoms and respiratory illnesses) as a result of exposure. The majority of epidemiological/community health investigations (16) examined substances reported to cause cancer as a result of exposure. Only four epidemiological/community health investigations examined substances reported to contribute to short-term respiratory effects as a result of exposure.
- Priority substances receiving the greatest attention in these studies were:
  - sulphur dioxide, PM<sub>2.5</sub>, ozone, and acid aerosols (substances reported to contribute to short-term respiratory effects)
  - benzene and 1,3-butadiene (substances reported to cause cancer)
- Authors of the human health risk/impact assessment studies concluded that no chronic health risks could be attributable to petroleum refinery air emissions.

- Authors of the epidemiological/community health investigations reported the following based on the study of populations residing in proximity to industrial areas with oil refineries and/or urban areas with oil refineries:
  - both “associations” and “no associations” were observed with respect to different cause-specific mortality and residence, and specific cancers and residence
  - associations were observed with respect to different pregnancy outcomes and residence, and different respiratory outcomes and residence
  - no associations were observed with respect to prevalence of odour perception and annoyance and residence
- Most of the studies of petroleum refinery air emissions were in urban areas with other emission sources and the contribution of petroleum refinery air emissions to total ambient air pollution in these areas was unknown.

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## GLOSSARY

**Acute Exposure:** Exposure to a chemical for less than 24 hours (Gallo 1996).

**Adverse Effect:** Any biochemical change, functional impairment, or pathologic lesion which impairs performance and reduces the ability of an organism to respond to additional challenge. An adverse effect may have different degrees of severity, and should be distinguished from adaptive (beneficial) effects and compensatory (neutral) effects (ITER).

**ATSDR:** US Agency for Toxic Substances and Disease Registry.

**Carcinogenesis:** The formation of tumors caused by chemical exposures. (Very likely a series of steps). The carcinogenic event modifies the genome and/or other molecular control mechanisms in the target cells such that these can give rise to a population of altered cells. The formation of benign and malignant tumors (i.e., cancers) is often considered together in determining a dose-response relationship and estimating a risk value for this endpoint. These effects are often considered not to have a threshold in response (ITER).

**Case-control study:** An observational study of persons with the disease (or other health outcome) of interest and a suitable control group of persons without the disease. The relationship of an “exposure” to the disease is examined by comparing the diseased and the non-diseased with regard to the frequency (or level) of past “exposure” (Last 1995).

**CCRIS:** Chemical Carcinogenesis Research Information System is a toxicology data file of the US National Library of Medicine’s Toxicology Data Network (TOXNET). It is a scientifically evaluated and fully referenced data bank, developed and maintained by the US National Cancer Institute.

**CEI:** CanTox Environmental Inc.

**ChemIDplus:** chemIDplus is a web-based search system that provides access to structure and nomenclature authority files used for the identification of chemical substances cited in US National Library of Medicine databases (<http://chem.sis.nlm.nih.gov/chemidplus/setupenv.html>).

**Chronic Exposures:** Repeated exposures for more than 12 months (Gallo 1996).

**CR:** Concentration ratio.

**CRL:** Cancer Risk Level for carcinogens. A CLR value represents predicted exposures multiplied by the carcinogenic potency of the chemical.

**COPC:** Chemicals of potential concern.

**Confidence interval:** The computed interval with a given probability (e.g., 95%) that the true value of a variable (e.g., a mean, a proportion, a rate) is contained within the interval (Last 1995).

**Cross-sectional study:** A study that examines the relationship between disease(s) (or other health-related characteristics) and other variables of interest (“exposures”) as they exist in a defined population at one particular time. The relationship between exposure and disease can be examined (1) in terms of the prevalence of disease in different population subgroups defined according to the presence or absence (or level) of the exposure of interest and (2) in terms of the presence or absence (or level) of the exposure of interest in the disease versus the non-diseased. Note that disease prevalence rather than incidence is usually recorded in a cross-sectional study. The temporal sequence of cause and effect cannot necessarily be determined (Last 1995).

**DART/ETIC:** DART/ETIC is a bibliographic database on the US National Library of Medicine's Toxicology Data Network (TOXNET). It covers teratology and other aspects of developmental and reproductive toxicology. It contains over 100,000 references to literature published since 1965 (<http://gibblins.net/SISRev3/Tox/SearchDART.html>).

**Deterministic Analysis:** Calculation and expression of health risks as single numerical values or "single point" estimates of risk. In risk assessments, the uncertainty and variability are discussed in a qualitative manner (US EPA 2003a).

**EC:** Environment Canada.

**Ecological bias:** The bias that may occur because an association observed between variables on an aggregate (ecological) level does not necessarily represent the association that exists at an individual level (Last 1995).

**Ecological study:** A study in which the units of analysis are populations or groups of people, rather than individuals. Errors in inference may result because associations may be artifactually created or masked by the aggregation process (Last 1995).

**EIA:** Environmental Impact Assessment.

**EMBASE:** Biomedical and pharmacological information database containing high-quality, current and validated biomedical and pharmacological information drawn from the international literature ([www.embase.com](http://www.embase.com)).

**ER:** An Exposure Ratio value represents the ratio of the estimated total chemical exposure dose ( $\mu\text{g}/\text{kg}/\text{day}$ ) from all pathways divided by the corresponding criteria dose (for non-carcinogens).

**Exposure:** An event that occurs when there is contact at a boundary between a human being and the environment with a contaminant of a specific concentration for an interval of time; the units of exposure are concentration multiplied by time (Last 1995).

**Exposure Pathway:** The course a chemical takes from the source to the exposed individual. An exposure pathway analysis links the sources, locations, and types of environmental releases with population locations and activity patterns to determine the significant pathways of human exposure (US EPA 2003a).

**Exposure Route:** The way a chemical comes in contact with a person (e.g., by ingestion, inhalation, dermal contact) (US EPA 2003a).

**GENE-TOX:** GENE-TOX is a toxicology data file of the US National Library of Medicine's Toxicology Data Network (TOXNET). It is created by the U.S. Environmental Protection Agency (EPA) and contains genetic toxicology (mutagenicity) test data, resulting from expert peer review of the open scientific literature, on over 3000 chemicals. The GENE-TOX program was established to select assay systems for evaluation, review data in the scientific literature, and recommend proper testing protocols and evaluation procedures for these systems (<http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?GENETOX>).

**HC:** Health Canada.

**HEAST:** US Environmental Protection Agency Health Effects Assessment Summary Tables.

**HSDB:** The Hazardous Substance DataBase is a toxicology data file on the US National Library of Medicine's Toxicology Data Network (TOXNET). It focuses on the toxicology of potentially hazardous chemicals. It is enhanced with information on human exposure, industrial hygiene, emergency handling procedures, environmental fate, regulatory requirements, and related areas (<http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>).

**IRIS:** The Integrated Risk Information System (IRIS) is a database of the U.S. EPA containing human health risk values for over 500 chemicals. The values represent the consensus of the U.S. EPA. IRIS can be accessed online at <http://www.epa.gov/iris/>. For additional information, contact the U.S. EPA Risk Information Hotline at (301) 345-2870 or at [Hotline.IRIS@epamail.epa.gov](mailto:Hotline.IRIS@epamail.epa.gov) (ITER).

**ITER:** The International Toxicity Estimates for Risk (ITER) is a database of international risk values, managed by Toxicology Excellence for Risk Assessment (TERA). ITER provides risk values from health organizations, government agencies and independent groups worldwide in a side-by-side format with a synopsis to explain any differences in values across organizations. ITER also provides a link to each organization for more detailed information. ITER is available at <http://www.tera.org/iter> (ITER 2003).

**LOAEL (lowest-observed-adverse-effect level):** The Lowest-Observed-Adverse-Effect-Level (LOAEL) is the lowest exposure level at which there are statistically or biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control group (ITER).

**MEDLINE:** Medical Literature, Analysis, and Retrieval System Online is the US National Library of Medicine's premier bibliographic database that contains over 12 million

references to journal articles in life sciences with a concentration on biomedicine ([http://www.nlm.nih.gov/databases/databases\\_medline.html](http://www.nlm.nih.gov/databases/databases_medline.html)).

**MTBE:** Methyl tertiary butyl ether.

**NAPS:** Environment Canada's National Air Pollution Surveillance.

**NIOSH:** US National Institute of Occupational Safety and Health.

**NOAEL(no-observed-adverse-effect level):** The No-Observed-Adverse-Effect Level (NOAEL) is an exposure level at which there are no statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and its appropriate control; some effects may be produced at this level, but they are not considered as adverse, nor precursors to adverse effects. In an experiment with several NOAELs, the regulatory focus is primarily on the highest one, leading to the common usage of the term NOAEL as the highest exposure without adverse effect (ITER).

**Odds ratio:** The ratio of two odds (cross-product ratio). The *disease-odds (rate-odds) ratio* for a cohort or cross-section is the ratio of the odds in favor of disease among the exposed to the odds in favour of disease among the unexposed (Last 1995).

**OSHA:** US Occupational Safety and Health Administration.

**PAH:** Polycyclic aromatic hydrocarbon.

**PM:** Particulate matter.

**PM<sub>2.5</sub>:** Particulate matter less than 2.5 microns in diameter.

**PM<sub>10</sub>:** Particulate matter less than 10 microns in diameter.

**PubMed:** On-line service of the US National Library of Medicine providing access to over 12 million MEDLINE citations back to the mid-1960's and additional life science journals. PubMed includes links to many sites providing full text articles and other related resources (<http://www.ncbi.nlm.nih.gov/PubMed/>).

**RfC:** **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 noncancer effects during a lifetime. RfCs are based on non-carcinogenic effects and are usually calculated by applying uncertainty factors to a NOAEL or LOAEL. Expressed in units of mg/m<sup>3</sup>. Used by the US EPA (ITER).

**RfD:** **Reference Dose** - an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs are based on non-carcinogenic effects and are usually calculated by applying uncertainty factors to a NOAEL or LOAEL. Expressed as mg/kg-day. Used by the U.S. EPA (ITER).

**Risk:** The probability of injury, disease, or death under specific circumstances. In quantitative terms, risk is expressed in values ranging from zero (representing the certainty that harm will not occur) to one (representing the certainty that harm will occur) (ITER).

**Risk Assessment:** The determination of the kind and degree of hazard posed by a chemical, the extent to which a particular group of people has been or may be exposed to the chemical, and the present or potential health risk that exists due to the chemical (ITER).

**TOXLINE:** US National Library of Medicine collection of online bibliographic information covering biochemical, pharmacological, physiological, and toxicological effects of drugs and other chemicals (<http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?TOXLINE>).

**TOXNET:** US National Library of Medicine Toxicology Data Network - cluster of databases on toxicology, hazardous chemicals, and related areas (<http://toxnet.nlm.nih.gov/>).

**TPHCWG:** Total Petroleum Hydrocarbon Criteria Working Group.

**TRI:** Toxics release inventory is an annually compiled series of databases that constitute the toxic releases files on the US National Library of Medicine's Toxicology Data Network (TOXNET). The database contains information on the annual estimated releases of toxic chemicals to the environment in United States and is based upon data collected by the US Environmental Protection Agency (<http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?TRI>).

**TSP:** Total suspended particulate.

**Standardized mortality (or morbidity) ratio (SMR):** The ratio of the number of deaths/cases of disease observed in the study population to the number that would be expected if the study population had the same specific rates as the standard population (Last 1995).

**Stochastic (Probabilistic) Analysis:** Calculation and expression of health risks using multiple risk descriptors to provide the likelihood of various risk levels. Probabilistic risk results approximate a full range of possible outcomes and the likelihood of each, which often is presented as a frequency distribution graph, thus allowing uncertainty or variability to be expressed quantitatively (US EPA 2003a).

**U.S. EPA:** United States Environmental Protection Agency. U.S. EPA information on *ITER* is compiled from EPA's Integrated Risk Information System (IRIS). IRIS can be accessed online at <http://www.epa.gov/iris/>. For additional information, contact the U.S. EPA Risk Information Hotline at (301) 345-2870 or at [Hotline.IRIS@epamail.epa.gov](mailto:Hotline.IRIS@epamail.epa.gov) (ITER).

**VOC:** Volatile organic compounds.

**WHO:** World Health Organization. Information on chemical assessments from the WHO will be added to *ITER* in the future (ITER).