Government of Canada Gouvernement du Canada

Assessment

Twenty-six Industry-Restricted Gas Oils and Kerosenes

Environment and Climate Change Canada
Health Canada

December 2023

Canada

Cat. No.: En84-339/2023E-PDF
ISBN: 978-0-660-48865-3

Environment and Climate Change Canada
Public Inquiries Centre
12th Floor, Fontaine Building
200 Sacré-Coeur Boulevard
Gatineau QC K1A 0H3
Telephone: 819-938-3860
Toll Free: 1-800-668-6767 (in Canada only)
Email: enviroinfo@ec.gc.ca

Aussi disponible en français

Synopsis

Pursuant to section 68 of the *Canadian Environmental Protection Act, 1999* (CEPA), the Minister of the Environment and the Minister of Health have conducted an assessment of 26 Industry-restricted Gas Oils and Kerosenes. The substances considered in this assessment have been identified as industry restricted as they may leave a petroleum-sector facility and be transported to other industrial facilities (for example, for use as a feedstock, fuel or blending component), but do not reach the public market in their original form. Their Chemical Abstracts Service Registry Numbers (CAS RN[1]) and their *Domestic Substances List* (DSL) names are listed in Appendix A. Fifteen additional CAS RNs with uses in products available to consumers were included in the draft assessment, which addressed 42 substances and was referred to under the Chemicals Management Plan as the Gas Oils and Kerosenes Group. However, as new information has been obtained that may impact characterization of their hazard, these 15 substances have been removed from this assessment, and are being evaluated in a separate assessment for Gas Oils and Kerosenes with Uses in Products Available to Consumers. Additionally, CAS RN 64742-88-7 was included in the draft assessment of Gas Oils and Kerosenes but, upon review, has been removed and is being evaluated along with other low boiling point naphthas in a separate assessment. Therefore, this assessment focuses on 26 Industry-restricted Gas Oils and Kerosenes.

Industry-restricted Gas Oils and Kerosenes are complex and highly variable combinations of hydrocarbons produced either directly through atmospheric distillation of crude oil or by the cracking of heavier vacuum distillation streams into lighter fractions, and are considered to be of Unknown or Variable composition, Complex reaction products or Biological materials (UVCBs). Gas oils contain straight and branched chain alkanes (paraffins), cycloalkanes (naphthenes), aromatic hydrocarbons, and mixed aromatic cycloalkanes, predominantly in the carbon range of C_9 to C_{30}. Kerosenes consist mainly of branched and straight chain alkanes and cycloalkane hydrocarbons in the range of C_9 to C_{16}.The aromatic hydrocarbon content of refinery stream gas oils and kerosenes can be variable, especially for the gas oils, and are typically in the range of 20 weight (wt)% to 80 (wt)%. For kerosenes, aromatic hydrocarbons do not normally exceed 25 volume (vol)%. Industry-restricted Gas Oils and Kerosenes may undergo further refinement for use as solvents, resulting in substances with much narrower carbon ranges, and in many cases, aromatic contents much lower than 20 wt%, while in many cases retaining the same CAS RNs as their original refinery streams. As a result, the carbon range and aromatic content of Industry-restricted Gas Oils and Kerosenes vary widely. Owing to their similarity of sources,

---

[1] The Chemical Abstracts Service Registry Number (CAS RN) is the property of the American Chemical Society and any use or redistribution, except as required in supporting regulatory requirements and/or for reports to the Government of Canada when the information and the reports are required by law or administrative policy, is not permitted without the prior, written permission of the American Chemical Society.

production, properties and hazard, Industry-restricted Gas Oils and Kerosenes have been grouped together in this assessment.

Some of the Industry-restricted Gas Oils and Kerosenes in this assessment were identified as being used as fuels and as fuel additives, in the oil and gas industry as petroleum production aids or processing aids, in automobile and light-duty motor vehicle manufacturing, and as laboratory substances. Other uses include the formulation of lubricants or lubricant additives, and of various products including oil-water separation aids, processing aids, and industrial coatings.

The ecological assessment uses a group-based approach that focuses on 26 Industry-restricted Gas Oils and Kerosenes. As there is a lack of information on when or if a CAS RN represents a refinery stream or a solvent, a range of aromatic contents from 20 wt% to 80 wt% is used. The compositional variability that exists within CAS RNs and between Industry-restricted Gas Oils and Kerosenes having different CAS RNs may lead to their interchangeable use (provided they meet property specifications).

Industry-restricted Gas oils and Kerosenes may be released to the environment from activities associated with production, transportation, and storage, as well as a result of commercial or industrial uses. They may be released from industrial sources to the aquatic environment through wastewater effluents, and to air. The identified uses of gas oils and kerosenes having the highest potential for release to the environment that are considered to be applicable to Industry-restricted Gas Oils and Kerosenes, and that are considered in this assessment are: formulation of lubricants or lubricant additives; formulation of various products including oil-water separation aids, processing aids, and industrial coatings; the use of processing aids by facilities in sectors including plastics and rubber, fabricated metal, machinery, and transportation equipment. An additional source with high potential for environmental release is the application of biosolids containing Industry-restricted Gas Oils and Kerosenes to agricultural land.

Environmental concentrations and compositions of Industry-restricted Gas Oils and Kerosenes in surface water following wastewater treatment were estimated and compared to modelled predicted no-effect concentrations based on their predicted composition in the effluent. Empirical and modelled aquatic toxicity data for Industry-restricted Gas Oils and Kerosenes indicate moderate to high hazard, while empirical soil toxicity data indicate low hazard.

Both low- and high-aromatic content Industry-restricted Gas Oils and Kerosenes were predicted to be unlikely to be causing harm to the environment when used in the above-mentioned applications. Components of Industry-restricted Gas Oils and Kerosenes might accumulate in sediment near points of discharge; however, there is no information on their environmental concentrations or impact of these substances to sediment-dwelling organisms.

Considering all available lines of evidence presented in this assessment, there is low risk of harm to the environment from the 26 Industry-restricted Gas Oils and Kerosenes in this assessment. It is concluded that the 26 Industry-restricted Gas Oils and Kerosenes in this assessment do not meet the criteria under paragraphs 64(*a*) or 64*(b)* of CEPA as they are not entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity, or that constitute or may constitute a danger to the environment on which life depends.

The critical health effects, identified in laboratory studies, for subchronic exposure to the Industry-restricted Gas Oils and Kerosenes are decreased body weight and increased organ weight. A critical health effect for the initial categorization of the Industry-restricted Gas Oils and Kerosenes was carcinogenicity, based primarily on classifications by international agencies. Based on the likelihood of Industry-restricted Gas Oils and Kerosenes to contain polycyclic aromatic hydrocarbons (PAHs), the European Commission classifies a number of the Gas Oils and Kerosenes CAS RNs as Category 1B (3 substances) carcinogens ("*may cause cancer*"), but considers these substances not carcinogenic if they are refined to contain less than 3 wt% PAHs as extracted by dimethyl sulfoxide (DMSO). Adverse reproductive and developmental effects were also considered in the risk characterization of the Industry-restricted Gas Oils and Kerosenes.

General population exposure to the Industry-restricted Gas Oils and Kerosenes may occur via releases to air from industrial facilities. Margins of exposure between upper-bounding estimates of exposure and critical effect levels are considered adequate to address uncertainties related to health effects and exposure. The potential for exposure via other environmental media is considered to be low.

The human health assessment took into consideration those groups of individuals within the Canadian population who, due to greater susceptibility or greater exposure, may be more vulnerable to experiencing adverse health effects. Subpopulations living near non-petroleum industrial facilities using gas oils and kerosenes who may have potential for higher exposures from emissions in the air were considered in the assessment.

Considering all the information presented in this assessment, it is concluded that the 26 Industry-restricted Gas Oils and Kerosenes in this assessment do not meet the criteria under paragraph 64(*c*) of CEPA as they are not entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger in Canada to human life or health.

It is therefore concluded that the 26 Industry-restricted Gas Oils and Kerosenes in this assessment do not meet any of the criteria set out in section 64 of CEPA.

Table of Contents

List of Tables

1. Introduction

Pursuant to section 68 of the *Canadian Environmental Protection Act, 1999* (CEPA) (Canada 1999), the Minister of the Environment and the Minister of Health have conducted an assessment of 26 Industry-restricted Gas Oils and Kerosenes to determine whether these substances present or may present a risk to the environment or to human health. These 26 gas oils and kerosenes were identified as priorities for assessment as they met categorization criteria as described in ECCC, HC (modified 2017) or were considered a priority through other mechanisms. The Chemical Abstracts Service Registry Numbers (CAS RN[2]) and *Domestic Substances List* (DSL) names of these 26 substances are listed in Table A.1 in Appendix A. Descriptions of each CAS RN as reported on the DSL are provided in ECCC (2022). Due to their similarity of sources, production, properties, and hazard, these 26 Gas Oils and Kerosenes have been addressed together in this assessment. Fifteen additional CAS RNs with uses in products available to consumers were included in the draft assessment, which addressed 42 substances and was referred to under the Chemicals Management Plan as the Gas Oils and Kerosenes Group. However, as new information has been obtained that may impact characterization of their hazard, these 15 substances have been removed from this assessment, and are being evaluated in a separate assessment for Gas Oils and Kerosenes with Uses in Products Available to Consumers. Additionally, CAS RN 64742-88-7 was included in the draft assessment of Gas Oils and Kerosenes but, upon review, has been removed and is being evaluated along with other low boiling point naphthas in a separate assessment. Therefore, this assessment focuses on 26 industry-restricted gas oils and kerosenes.

The substances considered in this assessment have been identified as industry-restricted, as they may leave a petroleum-sector facility and be transported to other industrial facilities (for example, for use as a feedstock, fuel or blending component), but do not reach the public market in their original form. The focus of the ecological assessment is on the 26 individual industry-restricted gas oil and kerosene substances identified in Appendix A. An upper aromatic content of 80 wt% is considered to be a reasonable worst-case for Industry-restricted Gas Oils and Kerosenes. Compositional variability exists within and between individual Industry-restricted Gas Oils and Kerosenes that can lead to their interchangeable use in products, provided they meet product use specifications.

This assessment does not consider the use of kerosenes in aviation fuels or of gas oils in fuels (for example, Fuel Oil No. 2) as these have been assessed previously

[2] The Chemical Abstracts Service Registry Number (CAS RN) is the property of the American Chemical Society and any use or redistribution, except as required in supporting regulatory requirements and/or for reports to the Government of Canada when the information and the reports are required by law or administrative policy, is not permitted without the prior, written permission of the American Chemical Society.

(Environment Canada, Health Canada 2014, 2015); however, available hazard data based on these substances are used to inform the human health effects assessment. In addition, some gas oils were addressed previously for site-restricted (1 CAS RN) or industry-restricted (2 CAS RN) uses (Environment Canada, Health Canada 2011, 2013). The use of gas oils as diesel fuels is not addressed in this assessment. This assessment also does not consider the use of Industry-restricted Gas Oils and Kerosenes as petroleum diluents, as this is more suitably considered in the context of the petroleum substance(s) that has been diluted.

This assessment includes consideration of information on chemical properties, environmental fate, hazards, uses, and exposures, including additional information submitted by stakeholders. Relevant data were identified up to August 2021. Additional data were submitted by stakeholders up to December 2019. Empirical data from key studies as well as some results from models were used to reach conclusions. When available and relevant, information presented in assessments from other jurisdictions was considered.

This assessment was prepared by staff in the CEPA Risk Assessment Program at Health Canada and Environment and Climate Change Canada and incorporates input from other programs within these departments. The ecological and human health portions of this assessment have undergone external written peer review and/or consultation. Comments on the technical portions relevant to the environment were received from Mr. Geoff Granville (GCGranville Consulting Corp) and Dr. Connie Gaudet (consultant). Comments on the technical portions relevant to human health were received from Dr. Glenn Talaska (University of Cincinnati, USA) and Dr. Susan Griffin (US EPA). Additionally, the draft of this assessment (published May 11, 2019) was subject to a 60-day public comment period. While external comments were taken into consideration, the final content and outcome of the assessment remain the responsibility of Health Canada and Environment and Climate Change Canada.

Assessments focus on information critical to determining whether substances meet the criteria as set out in section 64 of CEPA by considering scientific information, including information, if available, on subpopulations who may have greater susceptibility or greater concern, vulnerable environments and cumulative effects[3], and by incorporating a weight of evidence approach and precaution[4]. This assessment presents the critical information and considerations on which the conclusions are based.

---

[3] The consideration of cumulative effects under CEPA may involve an analysis, characterization and possible quantification of the combined risks to health or the environment from exposure to multiple chemicals.

[4]A determination of whether one or more of the criteria of section 64 of CEPA are met is based upon an assessment of potential risks to the environment and/or to human health associated with exposures in the general environment.

2. Identity of substances

Industry-restricted gas oils and kerosenes are known as UVCBs, which is an acronym for Unknown or Variable composition, Complex reaction products or Biological materials. These UVCB substances are complex combinations of hydrocarbon molecules that originate in nature or are the result of chemical reactions and processes that take place during processing and blending of petroleum. Given their complex and variable compositions, gas oils and kerosenes cannot practicably be synthesized by simply combining individual constituents. The complexity and variability of their compositions can make them difficult to fully and consistently characterize.

Gas oils consist predominantly of molecules in the carbon number range of C_9 to C_{30} and boiling over the interval of approximately 150 to 471 °C, as defined by the American Petroleum Institute (API), which is a United States trade association representing different facets of the oil and natural gas industries (API 2012a). The European petroleum industry organization Conservation of Clean Air and Water in Europe (CONCAWE) defines gas oils slightly differently than API, giving a predominant carbon range of C_{11} to C_{25}, and a boiling range of 150 to 450 °C (CONCAWE 1996a). Gas oils contain straight and branched chain alkanes (also referred to as straight and branched chain paraffins), cycloalkanes (naphthenes) aromatic hydrocarbons, and mixed aromatic cycloalkanes (API 2012a).

Gas oils can be produced directly through atmospheric distillation of crude oil, or they can be obtained from the cracking of heavier vacuum distillation streams into a lighter gas oil fraction. Cracking results in gas oils with higher amounts of aromatics and alkenes. Gas oils that are obtained through distillation with no or minimal additional processing are called straight run gas oils. Gas oils can be straight run, or a blend of straight run and/or cracked gas oil streams (API 2012a).

Kerosenes[5], the fraction of crude oil that boils approximately in the range of 150 to 290°C and consists of hydrocarbons approximately in the range of C_9-C_{16} (API 2010a), are considered together with the gas oils group as they are produced in a similar manner as gas oils (atmospheric distillation and/or cracking) (API 2010a) and represent the lighter end of the gas oil carbon range. Alkanes (normal, branched and cyclic) generally constitute at least 70% by volume (vol%) of kerosenes, while aromatic

---

For humans, this includes, but is not limited to, exposures from ambient and indoor air, drinking water, foodstuffs, and products available to consumers. A conclusion under CEPA is not relevant to, nor does it preclude, an assessment against the hazard criteria specified in the *Hazardous Products Regulations*, which are part of the regulatory framework for the Workplace Hazardous Materials Information System for products intended for workplace use. Similarly, a conclusion based on the criteria contained in section 64 of CEPA does not preclude actions being taken under other sections of CEPA or other Acts.

[5] Kerosenes are synonymous with kerosines and the terms appear interchangeably in the scientific literature.

hydrocarbons (mainly alkylbenzenes and alkylnaphthalenes) and alkenes are generally less than 25 vol% and 5 vol%, respectively (API 2010a, CONCAWE 1995). One CAS RN included in this assessment is a kerosene, 64742-91-2 (CONCAWE 1995), with the rest being gas oils. Operational definitions for the twenty-five gas oils and one kerosene in this report are included in ECCC (2022a).

The kerosene included in this assessment (CAS RN 64742-91-2; C_7-$C_{16;}$ 90 to 290 °C) falls partly outside the carbon and boiling point ranges for kerosene, although it is included in the CONCAWE kerosenes category (CONCAWE 1995). Five other substances (that is, CAS RNs 128683-26-1, 128683-28-3, 128683-29-4, 128683-30-7, and 129893-10-3) also fall partly outside of the carbon and boiling point ranges included in the above definition of gas oils (that is, collectively, the carbon ranges of the above substances span C_2 to C_{40}, and the boiling ranges span -38 to 550 °C). However, they are considered to be sufficiently similar to the other gas oils and kerosenes to include them in this assessment.

Compositional information on 88 refinery gas oil samples (representing 22 CAS RNs) was generated by the American Petroleum Institute. Percentage compositions for aromatic content ranged from less than 1 wt% to approximately 98 wt% (API 2014a). However, the <1 wt% and 98 wt% values were only found for single samples; most gas oil samples had aromatic contents in the 20 wt% to 80 wt% range. Compositional data were found for one sample of kerosene (CAS RN 8008-20-6) and for four samples of hydrodesulfurized kerosene (CAS RN 64742-81-0), which are not addressed in this assessment. No compositional data was found for the one kerosene included in this assessment, CAS RN 64742-91-2. The data for the kerosene substances indicated they had aromatic contents ranging from 14.7 to 31.4 wt%, of which mono-aromatics made up the majority (17.8-24.7 wt%) (API 2014b).

Additional processing of petroleum substances, such as gas oils and kerosenes may be undertaken to remove or reduce the levels of undesirable components, such as sulfur, nitrogen, aromatics, or alkenes, and increase the levels of cycloalkanes and isoalkanes. This also reduces their compositional variation (API 2010a, CONCAWE 1996a). The CAS name for petroleum substances describes only the last refining step undertaken at the refinery; therefore, the degree of refining and thus composition of a specific CAS RN in terms of the proportion of aromatics and aliphatics cannot be known based solely on the CAS RN, resulting in gas oils and kerosenes with the same CAS RN having a range of possible aromatic contents.

Furthermore, refinery stream gas oils and kerosenes may undergo further refinement for use as solvents. This greatly restricts the carbon range and, for many solvents, reduces the aromatic content to much less than 20 wt% with some less than 2 wt% (HSPA 2018). However, these refined solvents often continue to be described by the CAS RN used in their production (HSPA 2018). It is likely that some of the gas oils and kerosenes CAS RNs reported for various uses herein refer to these solvents and not to refinery stream gas oils and kerosenes; however, specific information on the carbon range or aromatic content of the solvents associated with these uses was generally not available.

An important characteristic of gas oils is the presence of polycyclic aromatic compounds (PACs), which collectively refers to polycyclic aromatic hydrocarbons (PAHs), their alkylated derivatives, and aromatics containing heteroatoms. Aromatic components have been shown to be the greatest contributors to the toxicity of petroleum substances (Swigert et al. 2014, Cermak et al. 2013). The aromatic fraction includes all components that contain an aromatic (that is, benzene) ring within the structure, and includes parent monoaromatic hydrocarbons (MAHs) and PAHs, as well as their alkylated derivatives (that is, MAHs and PAHs containing normal, branched or cyclic alkyl groups) and aromatics containing heteroatoms (that is, nitrogen, oxygen or sulfur atoms). Due to the lack of available information on whether a CAS RN represents a refinery stream or a solvent, a range of 20 wt% to 80 wt% aromatics was used in the ecological assessment, with the upper end of the range, 80%, considered as a worst-case scenario for the aromatics content of gas oils.

The alkyl substitutions in the PACs are usually 1-4 carbons long and can include non-carbon compounds such as sulfur (API 2012a). The relative abundance of the C_1-C_4 alkylated polycyclic aromatics in petroleum far exceeds the abundance of the non-alkylated parent compound (Speight 2007, Altgelt 1994). The levels of PACs, including heterocyclics, as well as polycycloalkanes, increase with increasing boiling point ranges of the fractions, while the levels of normal and branched alkanes and monocycloalkanes decrease (API 2012a). In light straight-run gas oils, the PACs are mainly 2- and 3-ringed compounds. The heavier atmospheric, vacuum or cracked gas oil components may contain increased levels of PACs with 4 or more rings (API 2012a). Petroleum streams from thermal or catalytic cracking processes generally have higher PAC contents than straight-run distillation fractions or streams derived from other non-cracking processes (for example, hydrotreating). Straight-run gas oil streams that have undergone a limited amount of additional processing are composed predominantly of saturated hydrocarbons (API 2012a).

Compositional information available for kerosenes (specifically, CAS RNs 8008-20-6, 64742-81-0 and 68333-23-3) indicates that these substances contain approximately 11 - 31 % aromatics, 65 - 83% saturates, and 1.4 - 15% alkenes (API 2014b). An analysis of a series of kerosenes found that virtually all of the aromatics had either one or two rings (API 2010a). As previously described, kerosenes generally have a lower aromatic content than gas oils. Generally, kerosenes contain <0.01 wt% of benzene (API 2010a, CONCAWE 1995). However, based on their carbon and boiling point range and depending on the degree of purification, gas oil and kerosene substances may have residual levels of benzene, plus low levels of toluene, ethylbenzene, and xylene components.

3. Physical and chemical properties

The composition and physical-chemical properties of gas oils and kerosenes vary with the source of crude oil or bitumen and the refining steps involved. General physical-chemical properties of gas oils and of kerosenes are presented in Table 3-1 and Table 3-2, respectively.

Table 3-1. General physical and chemical properties of gas oils

Property	Type	Value	Temperature (°C)	Reference
Pour point (°C)	Experimental	-30 to 0	-	API 2012b
Boiling point (°C)	-	150 to 450	-	API 2012a
Density (g/cm^3)	Experimental	0.8 - 0.99	15	ECB 2000a,b,c,d,e
Density (g/cm^3)	Experimental[a]	0.81- 0.90	15	CONCAWE 1996a
Vapour pressure (Pa)	Modelled	0.01 – 23	20	ECB 2000a,b,c
Vapour pressure (Pa)	-	≤ 133	20	MSDS 2013, 2014
Vapour pressure (Pa)[b]	-	280 -3520	21	Air Force 1989
Vapour pressure (Pa)	Modelled and experimental, for representative structures[b]	$3.6×10^{-9}$ - 384	20	ECCC 2022
Water solubility (mg/L)	-	< 10	20	ECB 2000b,c
Water solubility (mg/L)	Modelled, for representative structures[b]	<0.001-52	25	API 2012b
Water solubility (mg/L)	Measured[c]	2.0-8.7	5-20	API 2012b
Water solubility (mg/L)	-	Negligible	-	MSDS 2013, 2014, 2016
Water solubility (mg/L)	Modelled and experimental, for representative structures[b]	$8.6×10^{-11}$ – 95	20	ECCC 2022
Log K_{ow} (dimensionless)	Calculated	3.4 to 9.2	-	ECB 2000a,b,d,e

Property	Type	Value	Temperature (°C)	Reference
Log K_{ow} (dimensionless)	Modelled and experimental, for representative structures[b]	3.3 – 15	20	ECCC 2022

Abbreviations: K_{ow}, octanol–water partition coefficient; K_{oc}, organic carbon–water partition coefficient
- no data provided
[a] densities of automotive gas oil, and heating oil
[b] Based on representative structures of for typical gas oils with carbon length C_9 to C_{30}
[c] For Fuel Oil No. 2, (a gas oil)

Table 3-2. General physical and chemical properties of kerosenes

Property	Type	Value	Temperature (°C)	Reference
Boiling range (°C)	Measured	150 - 290	-	API 2010a
Vapour pressure (Pa)	Measured[a]	300 - 3500	21	API 2010a
Vapour pressure (Pa)[b]	Measured	1000	20	SDS 2021
Water solubility (mg/L)	Measured[b]	2.8 - 39	20-22	Murray et al. 1984, MacLeanL and Doe 1989, Sunito et al. 1986
Log K_{ow} range (dimensionless)	Modelled	3.3 to > 6	20	API 2010a

[a] For kerosene jet fuels
[b] For diesel fuel

To predict the physical/chemical properties and ecological fate of complex petroleum substances such as gas oils and kerosenes, representative structures are chosen from each chemical class present in these substances. As the compositions of gas oils and kerosenes are variable, representative structures could not be chosen based on their proportion in the mixture. This lack of general compositional data resulted in the selection of representative structures for alkanes, isoalkanes, alkenes, cycloalkanes, one-ring to six-ring aromatics, and alkyl-aromatics ranging from C_9 to C_{30}, based solely on carbon numbers for each hydrocarbon class. Physical–chemical data were assembled from scientific literature and from the EPI Suite (2008) group of environmental models. A summary of empirical and modelled physical and chemical property data for the representative hydrocarbon structures of the Industry-restricted Gas Oils and Kerosenes is provided in ECCC (2022).

It should be noted that the physical and chemical behaviour of the representative structures, when present as components in a UVCB substance, may differ from that of the pure form. The vapour pressures of components of a mixture are lower than their individual vapour pressures in accordance with Raoult's Law (that is, the total vapour pressure of an ideal mixture is proportional to the sum of the vapour pressures of the individual components multiplied by their mole fractions in the mixture). Similarly, the water solubilities of components in a mixture are lower than when they are present individually (Banerjee 1984; Di Toro et al. 2007). Concurrently when an individual petroleum hydrocarbon chemical that is normally solid under environmental conditions is part of a petroleum mixture (or UVCB), it may be found in a liquid state due to the lowering of its melting point when in a mixture (Di Toro et al. 2007). This results in an increase in the vapour pressure and water solubility of the hydrocarbon that is normally solid, as determined by the subcooled vapour pressure (Staikova et al. 2005) and subcooled solubility (Di Toro et al. 2007). The physical and chemical properties of the individual representative structures (Table 2.1 in ECCC 2022) give an indication of how these components of the petroleum mixture behave in the environment. This is discussed in Section 6.1.

4. Sources and uses

Information on a number of gas oils and kerosenes, including both the Industry-restricted Gas Oils and Kerosenes and other gas oils and kerosenes identified as priorities, was gathered through several surveys issued pursuant to section 71 of CEPA, as well as one voluntary data gathering initiative, as listed in Table 4-1. The 2011 survey (Environment Canada 2012) applied to all industrial sectors and collected information on the manufacture, import and use of 7 gas oils, only one of which is relevant to this assessment (CAS RN 64742-30-9), as the others have uses in products available to consumers. The 2015 survey (ECCC 2016a) collected information on industrial and commercial usage patterns, but not quantities, and included 14 Industry-restricted Gas Oils and Kerosenes. Information on the usage patterns of five Industry-restricted Gas Oils and Kerosenes were also reported to the 2015 voluntary data gathering initiative.

Table 4-1. Number of gas oils and kerones included in surveys issued pursuant section 71 of CEPA and a voluntary survey

Title of survey	Data reporting year / No. of GOs and Ks surveyed[a]	Survey reference	Data report reference
Notice with respect to certain high priority petroleum substances on the Domestic Substances List	2010 / 7 gas oils	Environment Canada 2011	Environment Canada 2012
Notice with respect to certain priority petroleum substances on the	2014 / 19 gas oils not included in previous survey	Environment Canada 2015	ECCC 2016a

Title of survey	Data reporting year / No. of GOs and Ks surveyed[a]	Survey reference	Data report reference
Domestic Substances List			
Voluntary data gathering initiative, 2015	2014 / 10 gas oils	NA	ECCC 2016b

[a] The number of gas oils and kerosenes CAS RNs prioritized for assessment included in the survey. The 42 gas oils and kerosenes prioritized for assessment includes the 26 Industry-restricted substances discussed in this report, as well as 16 other substances that are being evaluated separately in other reports, as discussed in Section 1.

The predominant use of gas oils is as intermediate blending components in the production of fuels that are used in diesel engines (that is, diesel fuel) and for heating (that is, fuel oil) (API 2012a). They may also serve as blending components for other fuels such as kerosene, gasoline, and aviation fuel, which leave the petroleum facility under different CAS RNs. Some gas oils are used in the production of products available to consumers.

The predominant use of kerosene in the United States is as aviation turbine fuel for civilian (using Jet A or Jet A-1 fuel) and military (using JP-8 or JP-5 fuel) aircrafts (API 2010a), and a similar usage profile is expected in Canada. Uses of gas oils and kerosenes as aviation fuels and as fuel oil no. 2 have been assessed previously (Environment Canada, Health Canada 2014, 2015). Kerosenes are also used as diesel fuel (No. 1), domestic heating fuel (Fuel oil No. 1), and illuminating kerosene (No.1-K), as well as being used as solvents in the formulation of a range of products including cleaning products, insecticides, antifoaming agents and mold release agents (CONCAWE 1995). The kerosenes used in these products are often of a narrower distillation range than those used in fuels and are often further treated to reduce odour and aromatics content (CONCAWE 1995).

Table 4-2 lists the uses of Industry-restricted Gas Oils and Kerosenes that were collected pursuant to a Section 71 survey (Environment Canada 2015), as well as a voluntary data-gathering initiative (ECCC 2016b).

Table 4-2. Usage Information on Industry-restricted Gas Oils and Kerosenes obtained from a CEPA section 71 survey and a voluntary survey (Environment Canada 2015; ECCC 2016b)

Use Category	CAS RNs
Automobile and light-duty motor vehicle manufacturing	92704-36-4
Confidential usage[a]	68333-88-0, 64741-43-1

Use Category	CAS RNs
Fuels (for example, gasoline, diesel, heating oil) and related products (for example, fuel additives)	68333-81-3, 64742-31-0
Laboratory substances	64741-43-1
Products used in oil & gas industry (for example, used in oil and gas extraction, cleaning product, processing aids)	68915-97-9, 68477-30-5, 68814-87-9, 68915-96-8, 64741-43-1, other (CBI)

Abbreviations: CBI - Confidential Business Information

[a] This use was declared as confidential business information. However, it was considered in the context of this risk assessment, and is not expected to have significant potential for releases.

The 26 Industry-restricted Gas Oils and Kerosenes are not used as formulants by Health Canada's Pest Management Regulatory Agency (PMRA) (PMRA 2010). (Personal communication, from Health Canada PMRA to Health Canada Risk Management Bureau, September 2017; unreferenced).

Information obtained from the Health Canada Food Directorate indicated the 26 Industry- restricted Gas Oils and Kerosenes are not identified as potentially being used in the manufacture of food packaging materials and/or as components of incidental food additives (Personal communication, from Health Canada Food Directorate to Health Canada Risk Management Bureau, August 2017; unreferenced). Further details are provided in Section 8.1.7.

None of the 26 Industry-restricted Gas Oil and Kerosene substances were identified as being used in cosmetic products (Personal communication, email from the Consumer Product Safety Directorate, Health Canada (HC) to the Existing Substances Risk Assessment Bureau (HC), August 3, 2017, personal communication, email from the NNHPD, Health Canada (HC) to the Existing Substances Risk Assessment Bureau (HC), August 3, 2017) or are listed in the Natural Health Products Ingredients Database (NHPID) and the Licensed Natural Health Products Database (LNHPD) (NHPID [modified 2017]; LNHPD [modified 2016].

The 26 substances included in this assessment were not found to have uses in products available to consumers in Canada or the US. This was determined through web, literature, SDS, and database searches, as well as information obtained through surveys issued pursuant to section 71 of CEPA and a voluntary data gathering initiative (Canada 2015a, ECCC 2016b).

5. Releases to the environment

Industry-restricted Gas Oils and Kerosenes may be released to the environment from activities associated with production, transportation, and storage, as well as a result of commercial or industrial uses. Fugitive releases of these gas oils from production, transportation and storage were assumed to follow the same pattern as found for industry-restricted gas oils assessed previously (Environment Canada, Health Canada 2013). Details on potential releases of gas oils within petroleum facilities from activities associated with processing these substances can be found in a previous assessment of Gas Oil [Site-Restricted] (Environment Canada, Health Canada 2011), and this information is also considered to apply to the processing of Industry-restricted Gas Oils and Kerosenes.

5.1 Releases from petroleum refineries

Gas oils and kerosenes originate from distillation columns as a distillate in a refinery or upgrader and may be refined by other processes following distillation. Thus, the potential locations for controlled releases of gas oils and kerosenes include relief, venting, or drain valves on the piping or equipment (for example, vessels). Under typical operating conditions, releases would be captured in a closed system, according to defined procedures, and returned to the processing facility or to the wastewater treatment system. In both cases, exposure of the general population is not expected.

Unintentional releases of gas oils and kerosenes may occur at production facilities. Existing legislation covers releases of gas oils and kerosenes and includes requirements at the federal, provincial, and territorial levels to prevent or manage the unintentional releases of petroleum substances and streams from facilities (SENES 2009). Non-regulatory measures (for example, guidelines, best practices) are also in place at petroleum sector facilities to reduce unintentional releases.

5.2 Releases from transportation

In general, three operating procedures are involved in the process of transportation: loading, transit and unloading. Loading and unloading of gas oils and kerosenes is normally conducted at sites with limited access to the general public.

The handling of gas oils and kerosenes at petroleum facilities for the purpose of transportation is regulated at both the federal and provincial levels, with legislation covering loading and unloading. Collectively, this legislation establishes requirements for the safe handling of petroleum substances and is intended to minimize or prevent potential releases during loading, transportation and unloading operations (SENES 2009).

Releases from washing or cleaning transportation vessels are not considered in this assessment, as tanks or containers for transferring petroleum substances are typically dedicated vessels and, therefore, washing or cleaning is not required on a routine basis (US EPA 2008).

Spills of gas oils and kerosenes during transportation and storage are considered in Section 5.4.

5.3 Releases from other industrial facilities

Based on the reported use patterns of these Industry-restricted Gas Oils and Kerosenes as discussed in Section 4, there is potential for releases to the aquatic environment through wastewater effluents from industrial sources other than petroleum refineries. Releases to the environment from industrial facilities are further discussed in Section 7.2. The potential for inhalation exposure to populations that may reside near these facilities is further discussed in Section 8.1.1.

5.4 Releases from spills

Gas oils and kerosenes may be spilled to the environment during storage, transport or use. For those gas oils and kerosenes which do not have any identified product use, spills are the only significant potential route for release to the environment.

Spill data for the five-year period 2012 to 2016 from Ontario, Alberta, Saskatchewan (the top five population centres only), Nunavut, the Yukon, the Northwest Territories, and British Columbia (for the one year period of March 2016 to March 2017, as well as the selected older spills data available on their website (British Columbia 2017) was compiled (ECCC 2022). Releases of aviation fuels and motor vehicle fuels were excluded. During this period, there were a total of 9 spills of gas oils or kerosense with a total reported volume of 2956 L. Most of this volume (2600 L) was from one spill at a pulp and paper facility, and it was reported that this spill was contained and was not expected to impact the environment. Given the small number and volume of spills reported from these provinces and territories, spills are not further considered in the context of this assessment.

6. Environmental fate and behaviour

6.1 Environmental distribution

When petroleum substances are released into the environment, the major fate processes include dissolution in water, volatilization, adsorption, biodegradation and photodegradation. These processes will cause changes in the composition of these substances.

As noted previously (Section 3), the solubility and vapour pressure of components within a mixture will be proportional to their concentrations in the mixture and thus lower than their individual water solubilities and vapour pressures.

Biodegradation almost always occurs when petroleum mixtures are released in the environment. Studies have found populations of bacteria and other organisms (for example, fungi and yeasts) that are capable of degrading petroleum hydrocarbons in both fresh and marine waters and sediments, as well as soils (Atlas 1981). Degradation may occur both in the presence and absence of oxygen. In general, aromatic components tend to be degraded more slowly than aliphatic components of similar size (that is, carbon number), though the degradation of some higher molecular weight cycloalkanes may be very slow (Atlas 1981; Potter and Simmons 1998). The rate of degradation tends to decrease as the size of the hydrocarbon increases. Three weathering processes—dissolution in water, volatilization, and biodegradation—typically result in the depletion of the more readily soluble, volatile, and degradable compounds and the accumulation of those most resistant to these processes in residues.

Gas oils and kerosenes are expected to be liquids at ambient temperatures. They are less dense than water, so if they are released to water, they will float on the water's surface while dissolution of the more soluble components is on-going.

Due to the complex interaction of components within a mixture that impacts their physical-chemical properties and behaviour, it is difficult to predict the fate of a complex mixture. Therefore, as a general indication of the fate of gas oils and kerosenes, the physical-chemical properties of representative structures of gas oils and kerosenes were examined (Table 2-1 in ECCC 2022), and are discussed below.

Components in the carbon range C_9–C_{30} are characterized by very low to moderate water solubilities (8.6×10^{-11} to 95 mg/L), very low to high vapour pressures (3.6×10^{-9} to 339 Pa), low to very high Henry's Law constants (0.03 to 2.1×10^{9} Pa·m^3/mol), moderate to very high log K_{ow} values (3.3 to 15), and moderate to very high log K_{oc} values (3.0 to 13) (Table 2-1 in ECCC 2022).

Based on their very low to low vapour pressures, the larger (≥C15) components of gas oils and kerosenes are not expected to partition significantly to air, while alkanes, which have moderate to high vapour pressures, will partition to air. In general, the smaller (≤C_{15}) structures of the other hydrocarbon classes including one and two-ring cycloalkanes, polycycloalkanes, and one- to three-ring aromatics will partition to some degree to air based on their moderate vapour pressures (Table 2-1 in ECCC 2022). However, as mentioned earlier, the behaviour of a mixture will differ from that of its representative components individually.

Gas oils and kerosenes are less dense than water (0.80–0.99 g/mL) (Table 3-1), thus upon entering water, the majority of components are expected to rise to the surface and spread out while only those components with higher water solubilities will enter the water column. Based on water solubility, the components less than C_{15} are expected to be the dominant components dissolved in the water column, including C_9-C_{10} cycloalkanes and C_9-C_{10} one-and two-ring aromatics, which have moderate water solubilities. All of the other representative structures of gas oils and kerosenes have low to very low water solubilities, with the larger structures having the lowest solubilities (Table 2-1 in ECCC 2022). Based on their combination of high to very high log K_{oc} values (3.0 to 13), very low to low water solubilities, and very low to low vapour pressures, the following components of Gas Oils and Kerosenes are expected to sorb to suspended solids and sediments (Table 2-1 in ECCC 2022): C_{30} one-ring cycloalkanes,

≥C_{10} two-ring cycloalkanes, ≥C_{22} polycycloalkanes, ≥C_{20} one- and two-ring aromatics, ≥C_{15} cycloalkane diaromatics, ,C_{30} 3-ring aromatics, and 4 to 6-ring aromatics.

If released to soil, all components of gas oils and kerosenes are expected to have high adsorptivity to soil particles, to the point of being relatively immobile for the largest structures, based on their estimated range of log K_{oc} values (3.0–13; Table 2-1 in ECCC 2022). However, from studies at contaminated sites, diesel fuel was found to be moderately mobile in soil, being able to move down through soil and along gradients. The speed of the movement is related to the volume of fuel, the type of soil and the gradient. Although no direct releases to soil are anticipated, indirect releases of the components of gas oils and kerosenes may result from the application of biosolids to land from wastewater treatment systems[6].

Gas oils and kerosenes are expected to form light non-aqueous-phase liquids (LNAPLs) in groundwater. Based on low to high solubility in water (8.6×10^{-11} to 95 mg/L), certain components will partition from the LNAPL into the groundwater. Lighter hydrocarbons are mobile and can be a problem at considerable distances from their point of release, due to transport in groundwater (CCME 2008). When large quantities of a hydrocarbon mixture enter the soil compartment, soil organic matter and other sorption sites in soil become fully saturated and the hydrocarbons will begin to form a separate phase (a non-aqueous phase liquid, or NAPL) in the soil. At concentrations below the retention capacity for the hydrocarbon in the soil, the NAPL will not move as a bulk phase (Arthurs et al. 1995); this is referred to as residual NAPL (Brost and DeVaull 2000). Above the retention capacity, the NAPL becomes mobile and will move as a bulk phase within the soil (Arthurs et al. 1995; Brost and DeVaull 2000).

6.2 Environmental persistence and bioaccumulation

Due to the complex nature of gas oils and kerosenes, their persistence and bioaccumulation potential were assessed based on empirical and/or modelled data for representative petroleum hydrocarbons expected to be similar to those that may be released into the environment. These representative structures do not include all possible components present within gas oils or kerosenes, nor do they necessarily provide a complete picture of the full range of the persistence potential for any given chemical class (for example, alkanes, one-ring aromatics) or carbon number (for example, C_{15}). Thus, the modelling results do not indicate the persistence and bioaccumulation potential of all components in a specific class and carbon range but

[6] In this assessment, the term "wastewater treatment system" refers to a system that collects domestic, commercial and/or institutional household sewage and possibly industrial wastewater (following discharge to the sewer), typically for treatment and eventual discharge to the environment. Unless otherwise stated, the term wastewater treatment system makes no distinction of ownership or operator type (municipal, provincial, federal, indigenous, private, partnerships). Systems located at industrial operations and specifically designed to treat industrial effluents will be identified by the terms "on-site wastewater treatment systems" and/or "industrial wastewater treatment systems".

instead give a more general indication of these properties. In addition, when available, empirical data on the persistence of the whole substance was considered.

6.2.1 Environmental persistence

Ultimate (ready) biodegradation tests were available for four gas oil samples and one straight-run kerosene, as described in API (2012a,b) and API (2010a,b). The ready biodegradation test results ranged from 56 to 64% mineralization within 28 days (the pass criterion is greater than 60% mineralization), which included a high aromatic and a lower aromatic content gas oil (75 wt% and 17 wt% aromatics, respectively), and commercial diesel fuel. However, as gas oils and kerosenes consist of hundreds of individual components, each with different susceptibilities to biodegradation, the results of such degradation studies can only indicate that some components are susceptible to biodegradation, and cannot determine the biodegradation potential of all components.

Under anoxic conditions (for example, in sediments), rates of biodegradation for gas oils are negligible (API 2012a).

Persistence of a suite of representative petroleum hydrocarbons for gas oils and kerosenes was characterized based on empirical and/or modelled data. Model results and the weighing of information are reported in the technical document on petroleum substance persistence and bioaccumulation (Environment Canada 2014) and results are summarized in ECCC (2022).

Empirical and modelled atmospheric half-lives for most representative structures of gas oils and kerosenes are less than 2 days, indicating that most gas oil and kerosene components are unlikely to persist in air (Environment Canada 2014). However, some three- to six-ring aromatic components, as well as C_{13} cycloalkane diaromatics have the potential to remain in the atmosphere for longer periods, allowing for their possible long-range transport to remote regions as a result of sorption to particulate matter in the atmosphere (Environment Canada 2014).

Based on their chemical structure, components of gas oils and kerosenes are not expected to hydrolyze under environmental conditions (Lyman et al. 1990; Environment Canada 2014).

On the basis of empirical and modelled biodegradation results for representative structures in water, soil, and sediment, the following components of gas oils and kerosenes are expected to have half-lives greater than 6 months in water and soils and greater than 1 year in sediments: C_{30} isoalkanes, C_{15}–C_{30} two-ring cycloalkanes, C_{18} and C_{22} polycycloalkanes, C_{12} one-ring aromatics, C_9–C_{20} cycloalkane monoaromatics, C_{10}–C_{30} two-ring aromatics, C_{12} cycloalkane diaromatics, C_{14} and C_{30} three-ring aromatics, C_{16} –C_{20} four-ring aromatics, C_{20}–C_{30} five-ring aromatics and C_{22} six-ring aromatics (Environment Canada 2014). In addition, the C_9–C_{12} dicycloalkanes, C_{14} polycycloalkanes, and C_9, C_{11}, and C_{15} to C_{30} one-ring aromatics have half-lives greater than 1 year in sediments, and therefore have high potential to persist in sediment.

6.2.2 Potential for bioaccumulation

Bioaccumulation potential for a suite of representative petroleum hydrocarbons expected to occur in gas oils and kerosenes was characterized based on empirical and/or modelled data. Bioaccumulation factors (BAFs) are the preferred metric for assessing the bioaccumulation potential of substances, as the bioconcentration factor (BCF) may not adequately account for the bioaccumulation potential of substances via the diet, which predominates for substances with log K_{ow} greater than approximately 4.5 (Arnot and Gobas 2003).

In addition to fish BCF and BAF data, bioaccumulation data for aquatic invertebrate species were also considered. Biota-sediment/soil accumulation factors (BSAFs), trophic magnification factors, and biomagnification factors were also considered in characterizing bioaccumulation potential.

Empirical and modelled bioaccumulation data for petroleum hydrocarbons can be found in Environment Canada (2014) and are summarized in Table 3-2 of ECCC (2022).

There is consistent empirical and predicted evidence to suggest that the following components of gas oils and kerosenes have the potential for high bioaccumulation with BAF/BCF values greater than 5000: C_{13}–C_{15} isoalkanes, C_{12} alkenes, C_{12}–C_{15} one-ring cycloalkanes, C_{12} and C_{15} two-ring cycloalkanes, C_{14} and C_{22} polycycloalkanes, C_{15} one-ring aromatics, C_{15}–C_{20} cycloalkane monoaromatics, C_{12}–C_{13} diaromatics, C_{20} cycloalkane diaromatics, C_{14} and C_{20} three-ring aromatics, C_{16}–C_{20} four-ring aromatics, C_{20}-C_{22} five-ring aromatics, and C_{22} six-ring aromatics. These components are highly lipophilic and are associated with a slow rate of metabolism in certain organisms such that the rate of uptake greatly exceeds the total elimination rate. However, most of these components are not expected to biomagnify (relative to their concentration in the diet) in aquatic or terrestrial food webs, largely because the combination of metabolism (albeit slow), growth dilution, and low dietary assimilation efficiency of these components allows the elimination rate to exceed the uptake rate when exposure occurs from the diet only (Environment Canada 2014). In addition, fish and other vertebrates have a higher capacity to metabolize aromatic components than do invertebrates, which decreases the potential for trophic transfer of these components. However, a study measuring PAHs and alkyl-PAHs in sea otters (Harris et al. 2011) suggests that some higher alkylated- three- and four-ring PAHs may biomagnify. While BSAFs were only found for some PAHs (Environment Canada 2014), it is possible that BSAFs will be greater than one for invertebrates, given that they do not have the same metabolic competency as fish. BSAFs will likely decrease beyond C_{22} due to reduced bioavailability of the higher boiling point fractions (Muijs and Jonker 2010). However, for a given PAH, slight increases in BSAFs for invertebrates were noted with increasing alkylation of the parent PAH, suggesting some degree of bioaccumulation in invertebrates (Harris et al. 2011).

7. Potential to cause ecological harm

7.1 Ecological effects assessment

7.1.1 Aquatic compartment

Due to the low water solubility of gas oils and kerosenes, most of the available toxicity tests were conducted using water accommodated fractions (WAFs). This approach is common in testing with poorly water soluble UVCBs such as petroleum products. WAFs are laboratory-prepared aqueous media derived from low-energy mixing of a poorly soluble test material such as a petroleum product. WAFs are essentially free of particles of bulk material, containing only the fraction that is dissolved or present as a stable dispersion or emulsion (Singer et al. 2001).

Exposure concentrations were not measured in the test solutions and results are reported in terms of the petroleum product loading rate[7] rather than concentrations (for example, a median lethal loading (LL_{50}) rather than a median lethal concentration (LC_{50})). This approach is common in testing with poorly water soluble UVCBs such as petroleum products.

Toxicity tests may also be conducted as water-soluble fractions (WSFs). In WSF studies, the test solutions are expressed in terms of the percent dilution of a WSF. Use of WSFs is not broadly supported because this method does not allow the ecotoxicity of the test substance to be expressed in terms of the amount of that test substance required to produce a particular effect (OECD 2000). Such results are not comparable to results obtained under WAF preparation methods (API 2012a).

Acute aquatic toxicity data (expressed as lethal loading/effective loading rates, LL/EL50 values) for gas oils and kerosenes is reviewed in API (2012a,b, 2010a,b) and are summarized in Table 7-1. The evaluation of the acute toxicity of the kerosenes category by API (2010a,b) included data on kerosene, sweetened (CAS RN 91770-15-9); solvent naphtha, hydrocracked heavy aromatic (CAS RN 101316-80-7); and hydrodesulfurized kerosene (CAS RN 64742-81-0). The toxicity data for each species category overlaps, though the kerosenes have a narrower range of toxicity values than dogas oils, likely because kerosenes have a smaller carbon range than gas oils.

[7] A loading rate is the amount of petroleum substance added to the exposure solution to generate a WAF or oil in water dispersion (OWD) and is reported in mg/L. When used to describe an effect endpoint, the loading rate is the amount of petroleum substance added to generate a WAF/OWD that results in the effect reported; for example, the lethal loading rate 50 (LL_{50}) is the amount of petroleum substance needed to generate a WAF/OWD that is lethal to 50% of the test organisms. A loading rate is not a direct measure of the concentration of the petroleum components dissolved in the exposure solution.

Table 7-1. Summary of acute toxicity of gas oils and kerosenes (API 2012a, 2010a,b)

Species Category	Gas oils LL50/EL50 (mg/L)	Gas oils: No. of CAS RNs, species[a]	Kerosenes LL50/EL50 (mg/L)	Kerosenes: No. of CAS RNs, species[a]
Fish	3.2 - 65	4, 6	18 - 25	3, 1
Aquatic invertebrates	0.51 - 210	5, 3	1.4 - 21	3, 1
Aquatic plants	0.28 - 25	4, 2	5.0 - 11	2, 1

[a] No. of CAS RNs for either gas oils or kerosenes that were tested. Species refers to species of fish, aquatic invertebrates or aquatic plants that were tested.

Abbreviations: EL_{50}, loading rate of test substance resulting in a specified effect (for example immobilization, growth) in 50% of the test species exposed to the WAF; LL_{50}, median lethal loading rate, loading rate of the test substance that results in 50% mortality in a population of test organisms exposed to the WAF; WAF, water-accommodated fraction, aqueous medium containing only the fraction of the petroleum substance that is dissolved or present as a stable dispersion or emulsion.

The available chronic toxicity data for gas oils and kerosenes includes two fish studies, one with a gas oil and one with a kerosene, and three daphnia studies with two gas oils and a kerosene. In the chronic gas oil study of Fuel Oil No. 2 with rainbow trout, *Oncorhynchus mykiss* (API 2012a), reduced survival and growth rates were seen at the highest loading rate WAF used in the test (3.0 mg/L), and the 28-day LL50 for survival was 2.7 mg/L. Rainbow trout and flagfish, *Jordanella floridae* were exposed to WSFs of JP-8 jet fuel (kerosene); the 128 day no observed effect concentrations (NOECs) were greater than 1.4-1.5 mg/L (Klein and Jenkins 1983). Chronic toxicity data were available for water flea, *Daphnia magna* exposed to a light hydro-cracked gas oil (HCGO) (CAS RN 64741-77-1) and a light catalytic-cracked gas oil (CCGO) (64741-59-9) with aromatic contents of 17 and 75%, respectively, and a hydro-desulfurized kerosene (HDK) (CAS RN 64742-81-0) with aromatic content of 17% (Table 7-2). Water-accommodated fractions (WAFs) were used as exposure solutions and results reported as both loading rates and measured concentrations of total dissolved hydrocarbons. Acute toxicity tests were also conducted with these two gas oils with green algae, *Raphidocelis subcapitata*, water flea, and rainbow trout. These studies are summarized in Table 7-2. The 21 day *D. magna* EL_{20} values with hydrodesulfurized kerosene and with catalytic cracked gas oil were 0.41 mg/L and 0.12 mg/L, respectively. The no-observable-effect loading rate (NOELR) with hydrocracked gas oil was 0.64 mg/L, which was the highest loading rate tested.

Table 7-2. Acute and chronic aquatic toxicity of two gas oils and a kerosene[a]

Test Organism	CAS RN (acronym)	Duration	Endpoint	Value (mg/L)[b]
rainbow trout *(Oncorhynchus mykiss)*	64741-77-1 (HCGO)	96 h	LL_{50} LC_{50}	>2.6 >0.54
rainbow trout *(Oncorhynchus mykiss)*	64741-59-9 (CCGO)	96 h	LL_{50} LC_{50}	>0.30 >0.21

Test Organism	CAS RN (acronym)	Duration	Endpoint	Value (mg/L)[b]
water flea (*Daphnia magna)*	64741-77-1 (HCGO)	48-hr	EL_{50} EC_{50} (immobilization)	5.5 1.0
water flea (*Daphnia magna)*	64741-59-9 (CCGO)	48-hr	EL_{50} EC_{50} (immobilization)	0.51 0.45
green algae *(Raphidocelis subcapitata*[c]*)*	64741-77-1 (HCGO)	96-h	EL_{50} (cell density/growth rate) EC_{50} (cell density, growth rate)	3.0, 5.3 0.51, 0.85
green algae *(Raphidocelis subcapitata*[c]*)*	64741-59-9 (CCGO)	96-h	EL_{50} (cell density/growth rate) EC_{50} (cell density, growth rate)	0.31, 0.80 0.25, 0.70
water flea (*Daphnia magna)*	64741-77-1 (HCGO)	21 d	EL_{50} (reproduction) EC_{50} (reproduction) NOELR LOELR NOEC LOEC	Not calculable Not calculable 0.64 >0.64 0.13 >0.13
water flea (*Daphnia magna)*	64742-81-0 (HDK)	21 d	EL_{20} (survival) EC_{20} (survival)	0.41 0.08
water flea (*Daphnia magna)*	64741-59-9 (CCGO)	21 d	EL_{20} (reproduction) EC_{20} (reproduction)	0.12 (0.08-0.16) 0.09 (0.06-0.12)

[a] References: Swigert et al. 2014, API (2010b, 2012b)

[b] Bracketed values refer to the 95% confidence interval.

[c] *Raphidocelis subcapitata* is formerly known as *Pseudokirchneriella subcapitata* and *Selenastrum capricornutum.*
Abbreviations: HCGO – hydrocracked gas oil; CCGO – catalytic cracked gas oil; HDK – hydrodesulfurized kerosene; EL_X, median effect loading rate, loading rate of the test substance that results in a specified effect in x% of the test organisms exposed to the water accommodated fraction (WAF); ; EC_X, percent effect concentration, concentration of the test substance that results in a specified effect in x% of the exposed test organisms; LC_{50}, median lethal concentration of the test substance that results in 50% mortality in a population of exposed test organisms; LL_{50}, median lethal loading rate, loading rate of the test substance that results in 50% mortality in a population of test organisms exposed to the WAF; NOELR, no observed effect loading rate; LOELR, lowest observed effect loading rate; LOEC, lowest observed effect concentration.

Some chronic mesocosm tests with Fuel Oil No. 2 (a gas oil) were conducted that showed significant effects on the community structure and density of the benthic, meiobenthic and inbenthic invertebrate organisms, as well as the phytoplankton community at levels of 61-190 µg/L (Stacey and Marcotte 1987; Grassle et al. 1981; Vargo et al. 1982; Bott and Rogenmuser 1978). These studies are more fully described in Environment Canada and Health Canada (2015).

CONCAWE has developed an aquatic toxicity model specifically for petroleum hydrocarbon mixtures, called PETROTOX (2011). This model is based on chemical action via non-polar narcosis for acute toxicity, the primary mode of action for all petroleum hydrocarbons (CONCAWE 1996a), and accounts for additive effects within the petroleum mixture by using a toxic unit approach. PETROTOX estimates petroleum hydrocarbon toxicity for substances in the C_4–C_{41} range that are dissolved in the water fraction.[8] Substances smaller than C_4 are considered too volatile to impart significant toxicity, while those larger than C_{41} are considered too hydrophobic and immobile to impart significant aquatic toxicity. The model can also estimate a chronic NOELR by utilizing an average acute-to-chronic ratio (ACR). PETROTOX v.3.06 uses an ACR of 3.83; however, more recent analysis has adjusted the average ACR to 5.22 (McGrath et al. 2018). Therefore, the ACR in PETROTOX v.3.06 was manually adjusted to 5.22 when calculating chronic values. The model generates toxicity estimates in terms of loading rates (for example, a median lethal loading (LL_{50}) rather than a median lethal concentration (LC_{50}), thereby accounting for the poor solubility of petroleum substances in water.

Redman et al. (2012) reported measured acute LL_{50}s or EC_{50}s of petroleum products including gas oils and kerosenes from other studies, for the green algae, *R. subcapitata*, *D. magna*, and *O. mykiss.* Redman et al. (2012) also used the PETROTOX model to generate predicted toxicity values from these empirical studies, where sufficient analytical data were available. The measured and associated predicted values are summarized in Table 4-1 in ECCC (2022). The PETROTOX predictions based on data from the empirical studies were in general lower than the measured values from the same studies indicating that the PETROTOX estimates are slightly protective.

PETROTOX was used to compare the acute aquatic toxicities of gas oils and kerosenes with 20 wt% aromatics, and also to compare them with the aquatic toxicity of gas oils with high (80 wt%) aromatic content, for a variety of species, including fish, invertebrates and algae. For gas oils, a boiling point range of 150-450 °C was used, and for kerosenes, a boiling point range of 150-290 °C was used. The acute toxicities of gas oils and kerosenes with 20 wt% aromatics are similar for most species, including the most sensitive species (Table 4-2 in ECCC 2022). Gas oils with 80 wt% aromatics are

[8] PETROTOX uses its own library of petroleum hydrocarbons and their associated physical and chemical properties. These properties may differ from those given for the same representative structures in ECCC (2020a).

an order of magnitude more hazardous than gas oils or kerosenes with 20 wt% aromatics (Table 4-2 in ECCC 2022).

The acute toxicity values for gas oils and kerosenes generated for *D. magna, R. subcapitata* and *O. mykiss* with PETROTOX (Table 4-2 in ECCC 2022) are mostly similar to the empirical acute values (LL50s of 0.31-5.5 mg/L; Table 7-2), with the exception of the estimated value of 25 mg/L for *D. magna* for 20 wt% aromatic gas oils, which is an order of magnitude higher than the empirical value of 5.5 mg/L for a 17% aromatic light hydrocracked gas oil (Table 7-2). The chronic EL_{50} values for *D. magna* (0.41 mg/L for a low aromatic kerosene and 0.12 mg/L for high aromatic gas oil; Table 7-2) are also within one order of magnitude of the PETROTOX modelled chronic values for *D. magna* (0.12 mg/L and 0.018 mg/L for 20% aromatic kerosenes and 80 wt% aromatic gas oils, respectively; Table 4-4 in ECCC 2022). Therefore, the modelled data from PETROTOX are generally conservative (protective of the environment), and align with the experimental toxicity values.

PETROTOX modelling was also used to estimate the acute and chronic toxicities of the post wastewater treatment compositions of gas oils with 80 wt% aromatics and of gas oils and kerosenes with 20 wt% aromatic content (Tables 4-3 to 4-5 in ECCC 2022). Domestic and industrial wastewater treatment systems are considered to be the major sources of release of Industry-restricted Gas Oils and Kerosenes to the aquatic environment, based on an analysis of their properties, use patterns, and common industrial practices (Section 7.2). As gas oils and kerosenes consist of hundreds of individual components, each with its own physical and chemical properties that impact its removal during wastewater treatment, such treatment will result in the differential removal of components of gas oils and kerosenes. Thus, the relative proportion of individual components in the gas oil or kerosene released following wastewater treatment is different from that of the gas oil or kerosene that originally entered the treatment system.

In order to determine the toxicity of the modified gas oils and kerosenes released in effluent following wastewater treatment, the removal of hydrocarbons during wastewater treatment and thus, the composition of the post-wastewater treatment gas oils and kerosenes, were estimated using a hydrocarbon block method developed by CONCAWE (1996c). The estimation of the removal of hydrocarbons uses the library of hydrocarbon representative structures, their physical-chemical properties, and the mapping scheme of hydrocarbons to certain hydrocarbon blocks found in PETROTOX v3.06 (2011). The percent removal of hydrocarbon blocks during wastewater treatment is estimated based on the removal of individual hydrocarbon representative structures using a wastewater treatment model (SimpleTreat version 3.1 (SimpleTreat 2003)). This model estimates removal of substances via sorption, volatilization and degradation but does not provide information on degradation products. From this, the new relative proportion of components in the gas oil or kerosene following wastewater treatment was estimated based on the hydrocarbon blocks, and PETROTOX was used to estimate the acute toxicities and the chronic NOELRs for seven aquatic species utilizing the post-wastewater treatment composition of the released gas oils and/or kerosenes. PETROTOX was run using low-resolution mode and two boiling point ranges; one based on the boiling point range for C_9 to C_{19} n-alkanes (115-336 °C) and one based on the boiling point range for n-alkanes greater than C_{19} to C_{30} (336.1-454 °C) (Table 7-3; Tables 4-3 and 4-4 in ECCC 2022). The lowest chronic NOELR for the most sensitive species was used as the critical toxicity value (CTV).

Toxicity to most test species increased slightly following wastewater treatment in a wastewater treatment system (WWTS) (Table 7-3) as the composition of the first hydrocarbon block (C_9-C_{19}) shifted to a higher proportion of aromatics. However, the overall mass of gas oils and kerosenes in the post-treatment effluent decreased by about 88% for the high (80 wt%) aromatic scenario and by about 91% for the low (20 wt%) aromatic scenario, leading to greatly reduced overall toxicity post-WWTS due to the reduction in mass in the treated effluent. The aromatic content of the second hydrocarbon block (greater than C_{19}-C_{30}) post-treatment stayed similar to its pre-treatment in the 20% aromatic content scenario, with a small decrease (5%) in the aromatics content in the 80% aromatic content scenario.

Table 7-3. PETROTOX low resolution modelled chronic aquatic toxicity (NOELR (mg/L) of high-aromatic and low-aromatic gas oils and kerosenes before and after wastewater treatment

Test organism	Common name	High arom. 80:20 Ar:Al	Post-WWTS High arom.	Low arom. 20:80 Ar:Al	Post-WWTS Low arom
Oncorhynchus mykiss	Rainbow trout	0.0094	0.0092	0.053	0.037
Pimephales promelas	Fathead minnow	0.020	0.019	0.14	0.088
Daphnia magna	Water flea	0.018	0.018	0.12	0.080
Raphidocelis subcapitata[a]	Green algae	0.026	0.025	0.13	0.090
Palaemonetes pugio	Grass shrimp	0.0080	0.0078	0.043	0.030
Rhepoxynius abronius	Marine amphipod	0.0041	0.0040	0.020	0.014
Menidia beryllina	Inland silverside	0.063	0.060	0.92	0.45

[a] *Raphidocelis subcapitata* is formerly known as *Pseudokirchneriella subcapitata* and *Selenastrum capricornutum.*
Abbreviations: NOELR - no observed effect loading rate; Ar:Al, aromatic : aliphatic ratio; WWTS – wastewater treatment system

PETROTOX was also used in high-resolution mode with compositional data available for hydrodesulfurized kerosene (HDK) (17-23% aromatics) and light catalytic cracked gas oil (CCGO) (75-84% aromatics) (API 2012c, 2013a) to model the chronic toxicities of these substances before and after wastewater treatment (Table 7-4). The chronic NOELRs generated for HDK (low aromatic kerosene) in high resolution mode were found to be very similar to those generated in low-resolution mode for a gas oil with 20% aromatics (Table 7-3). The low-resolution chronic NOELRs for a gas oil with 80%

aromatics (Table 7-3) were lower, but within an order of magnitude of the NOELRs generated for high aromatic gas oil (CCGO).

Table 7-4. PETROTOX high resolution modelled chronic aquatic toxicity (NOELR in mg/L) of a high aromatic gas oil[a] and a low aromatic kerosene[b] before and after wastewater treatment

Test organism	Common name	High arom. GO	Post-WWTS High arom GO	Low arom. kerosene	Post-WWTS Low arom kerosene
Oncorhynchus mykiss	Rainbow trout	0.030	0.038	0.056	0.061
Pimephales promelas	Fathead minnow	0.058	0.070	0.11	0.12
Daphnia magna	Water flea	0.054	0.066	0.11	0.12
Raphidocelis subcapitata[c]	Green algae	0.037	0.038	0.11	0.10
Palaemonetes pugio	Grass shrimp	0.026	0.033	0.048	0.052
Rhepoxynius abronius	Marine amphipod	0.014	0.018	0.025	0.027
Menidia beryllina	Inland silverside	0.15	0.17	0.40	0.43

[a] compositional data for light catalytic cracked gas oil, CAS RN 64741-59-9 (API 2013a)
[b] compositional data for hydrodesulfurized kerosene, CAS RN 64742-81-0 (API 2012c)
[c] *Raphidocelis subcapitata* is formerly known as *Pseudokirchneriella subcapitata* and *Selenastrum capricornutum.*
Abbreviations: GO – gas oil; K – kerosene; NOELR no observed effect loading rate; WWTS – wastewater treatment system

Gas oils and kerosenes may be further refined to produce hydrocarbon solvents with narrower carbon ranges and sometimes lower aromatics contents for uses in various applications. The toxicity of one of the five hydrocarbon solvent categories (as defined by the Hydrocarbon Solvents Producers Association (HSPA), which was the only solvent category associated with CAS RNs considered in this assessment (HSPA 2018), was modelled post-wastewater treatment to determine how the additional refining affects its toxicity compared to full-range gas oils (for example, C_9-C_{30} hydrocarbons) (ECCC 2022). The NOELR for this aromatic solvent with carbon range C_{14} – C_{20} and a maximum of 30% aromatics was 0.011 mg/L. This NOELR is less hazardous than those for full-range gas oils having 20 to 80% aromatics (0.014 mg/L and 0.004 mg/L, respectively; Table 7-3). Therefore, the toxicity of the full-range gas oils is used as a conservative estimate of the toxicity of the Industry-restricted Gas Oils and Kerosenes in this assessment, including those used as solvents.

As gas oils and kerosenes can have differing aromatic contents, which affect their toxicity, both high and low aromatic content gas oils and kerosenes were considered for the purpose of CTV derivation. A range of 20% to 80% aromatics was chosen to represent the typical range of aromatics found in gas oils and kerosenes (Section 2). The high end of this range is not applicable to most kerosenes, as they typically have a maximum aromatics content of about 30 wt% (Section 2). The chronic toxicity of kerosenes (boiling point range of 150-290 °C) with an aromatics content of 30% was modelled with PETROTOX in low-resolution mode, and was found to be similar to that of low-aromatics gas oils and kerosenes (20% wt) aromatics (Table 4-6 of ECCC 2022). Therefore, it is considered that the modelling for low aromatics gas oils and kerosenes is a good representation of the ecotoxicity of a kerosene with high aromatics content.

As these substances will persist in water long enough to have the potential to cause chronic toxicity (Section 6), chronic aquatic toxicity values were considered to be most relevant for CTV derivation. Petroleum hydrocarbons, such as gas oils and kerosenes, are expected to have similar toxicities to both freshwater and marine species, as they are non-polar narcotics, and therefore will not be affected by the dissolved salts present in greater quantities in seawater. Therefore, aquatic toxicity data for both freshwater and marine species were considered for the choice of the aquatic CTV.

The CTVs for modelled chronic toxicity with the most sensitive species (*Rhepoxynius abronius*) with the modelled post-wastewater treatment composition gas oils and kerosenes are a NOELR of 0.004 mg/L for gas oils and kerosenes with high (80%) aromatic content, and a NOELR of 0.014 mg/L with low (20%) aromatic content (Table 7-3). These values for *R. abronius* are within one order of magnitude of most of the chronic values obtained for the six other aquatic species modelled (Table 4-4 in ECCC (2022). These values were modelled in low-resolution mode, as these low-resolution values were found to be similar to, or slighter lower than, those modelled in high-resolution mode with the compositional data available for one gas oil and one kerosene (Table 7-4).

As the CTVs are chronic values for the most sensitive species, no assessment factor was added to convert the CTVs to predicted no-effect concentration (PNECs), so the PNECs are the same as the CTVs.

7.1.2 Sediment compartment

Only one sediment toxicity study for gas oils or kerosenes was found: marine sediments contaminated as a result of Jet Fuel JP-5 (a kerosene) spillage were reported to contain residues that were still lethal to juvenile clams for more than 5 years after the spill (Dow 1978).

The toxicity of gas oils and kerosenes to invertebrates, including several species of sediment-dwelling aquatic worms has been reviewed in CONCAWE (1995,1996a) and summarized in Table 4-7 in ECCC (2022). However, exposure of the worms was through water, and not through sediment. One study that included two species of polychaete worms was available for no. 2 fuel oil (a gas oil). For kerosenes, three studies were available that included four species of aquatic worms. Acute effects of No. 2 fuel oil as well as kerosenes to aquatic worms were mostly in the range of 1 to 3 mg/L, with the exception of one of the kerosene studies with mortality of 1-8% observed at greater than 2000 mg/L. Empirical acute toxicity data for daphnia from Redman et al. (2012) (Table 4-1 in ECCC 2022) is within the same range or lower than these values for aquatic worms (Table 4-7 in ECCC 2022). PETROTOX modelled low aromatic acute values for daphnia and other aquatic invertebrates are similar (0.20-25 mg/L) (Table 4-2 in ECCC 2022a). The PETROTOX modelled acute invertebrate values for high aromatic gas oils and kerosenes are one to two orders of magnitude lower (0.03-0.20 mg/L) (Table 4-2 in ECCC 2022).

Three toxicity studies on synthetic oil-based drilling mud fluids towards various sediment organisms were found, as summarized in ECCC (2022). The synthetic drilling mud fluids tested contained high concentrations of *n*-alkanes and/or isoalkanes, with carbon numbers in the C_9-C_{32} range. These studies indicate these low aromatic content substances have low toxicity to sediment organisms: Payne et al. (2001) determined an acute 10-day LC_{50} of approximately 6300 mg/kg dry weight (dw) of C_{11}-C_{19} for the amphipod *R. abronius*. No adverse effects were observed for winter flounder (*Pleuronectes americanus*) exposed to 21 to 1500 mg/kg dw sediments of drill cutting fluids containing mainly aliphatic hydrocarbons (Payne et al. 1995). Likewise, no adverse effects were observed for American lobster (*Homarsus americanus*) exposed orally to synthetic drilling muds composed mainly of isoalkanes and free of aromatic compounds (1 mL every 3 to 4 days administered orally for a total of 5 mL) (Hamoutene et al. 2004).

A CTV and PNEC for sediment organisms could not be determined, due to the lack of data on the toxicity of gas oils and kerosenes to organisms through sediment exposure, other than for oil-based drilling mud fluids, which contain very low aromatic content, and therefore may not be generally representative of Industry-restricted Gas Oils and Kerosenes.

7.1.3 Terrestrial compartment

Diesel fuel (a gas oil) has been found to be hazardous to plants and soil invertebrates at levels of 10 000 mg/kg wet wt. (Shin et al. 2005) to 50 000 mg/kg (Adam and Duncan 1999), though the effects may be species-specific (Adam and Duncan 1999). Application of 0.74-2.3 L/m^2 of gas oils and kerosenes were found to have effects on grain yield, seed germination and plant growth (Warner et al. 1984, Wang and Bartha 1990). Terrestrial toxicity data is summarized in ECCC (2022).

The Canada-wide Standards for Petroleum Hydrocarbons (CCME 2008) provide soil standards for petroleum substances based on toxicity to a variety of terrestrial organisms (invertebrates, plants). These standards are based on four fractions of total petroleum hydrocarbons (TPH): F1 (C_6–C_{10}), F2 (greater than C_{10} to C_{16}), F3 (greater than C_{16} to C_{34}) and F4 (greater than C_{34}) and assume an 80:20 ratio of aliphatics to aromatics. Fractions 2 and 3 encompass the carbon range of gas oils and kerosenes. The standards are also divided into four land-use classes (agricultural, residential, commercial, industrial) and two soil types (coarse grained and fine grained soils) for the determination of remedial standards. The most sensitive land-use and soil type is typically agricultural coarse-grained soils. The standards for F2 and F3 in agricultural coarse-grained soils are 150 and 300 mg/kg dw of soil, respectively (CCME 2008). As gas oils could fall into both of these categories, the lower value, 150 mg/kg dw of soil for F2, was selected as the CTV for terrestrial exposure. This same value was used for kerosenes, as they most resemble F2. As these Canada-Wide Standards were developed to protect key ecological receptors in the soil (CCME 2008), and were chosen for the most protective scenario (that is, coarse-grained agricultural soils), no assessment factor was applied to convert the CTV to the PNEC.

7.2 Ecological exposure assessment

Due to the limited environmental exposure data available for industry-restricted Gas Oils and Kerosenes, the ecological exposure assessment used available data for all 42 prioritized gas oils and kerosenes[9] (Environmental Canada 2012, ECCC 2016a,b). Based on this data, the sources with the greatest potential for releases of Industry-restricted Gas Oils and Kerosenes to the environment are considered to be:

- formulation of lubricants or lubricant additives;
- formulation of various products including oil-water separation aids, processing aids, and industrial coatings;
- the use of processing aids by such facilities as plastics and rubber, fabricated metal, machinery, and transportation equipment; and
- the application of biosolids to agricultural soils.

These sources are therefore considered in the exposure scenarios described below.

7.2.1 Estimation of removal of petroleum components during wastewater treatment

The release of gas oils and kerosenes from industrial facilities generally results in a discharge to systems that treat wastewater prior to release to the aquatic environment. The composition of the components of gas oils or kerosenes that remain following wastewater treatment will differ from their original composition.

CONCAWE's (1996c) hydrocarbon block method, described in section 7.1.1, was used to estimate the removal of petroleum hydrocarbons during wastewater treatment, such that the post-wastewater treatment composition and concentration in effluent could be determined. The estimated removal (90% on average for gas oils and kerosenes with aromatic mass fraction ranging from 20% to 80%) was used to estimate the predicted

[9] The 42 gas oils and kerosenes prioritized for assessment includes the 26 Industry-restricted gas oils and kerosenes discussed in this assessment, as well as 16 other gas oils and kerosenes that are evaluated separately in other reports, as discussed in Section 1.

environmental concentration (PEC) of the Industry-restricted Gas Oils and Kerosenes in the receiving water. The estimated removal rate of 90% is applicable to not only the Industry-restricted Gas Oils and Kerosenes but also to all gas oils and kerosenes with aromatic mass fraction in the range of 20-80%.

7.2.2 Formulation of lubricants or lubricant additives

The formulation facilities identified for lubricants or lubricant additives are mainly indirect dischargers (discharging their wastewater to sewers). A conservative PEC was estimated based on the largest facility in Canada, with the maximum annual lubricant formulation capacity not exceeding 1 000 000 tonne/yr (Environment Canada 2013) and an estimated 300 production days per year (ECB 2003). The facility's wastewater discharge was estimated as 333 300 L/d based on an estimated discharge rate of 100 L per tonne of lubricants formulated (OECD 2004). The maximum quantity of gas oils and kerosenes potentially released from this facility to sewer was estimated as 5 kg/d, based on the facility's estimated wastewater discharge and a typical sewer discharge limit for oil and grease (15 mg/L, as in the case of Toronto (2014). The quantity released to receiving water was estimated as 0.5 kg/d by applying the estimated average wastewater treatment removal rate of 90%, as described above. The daily water volume was calculated as the product of the effluent flow of the local wastewater treatment system and the dilution factor of the receiving water near the discharge point. The aquatic PEC of the Industry-restricted Gas Oils and Kerosenes for the formulation of lubricants or lubricant additives was thus estimated as 3.3 μg/L based on a daily receiving water volume of 151 million L/d near the discharge point of the local wastewater treatment system receiving the facility's discharge.

The estimated PEC is considered to be a very conservative value because it is based on the highest release as estimated for the maximum formulation capacity for the largest facility in Canada. Adding to the conservatism of this PEC is that it is applicable to not only the Industry-restricted Gas Oils and Kerosenes but also to all gas oils and kerosenes with aromatic mass content in the 20%-80% range. In addition, the use of the sewer discharge limit for oil and grease in the calculations implicitly assumes that gas oils and kerosenes comprise the entirety of the discharged oil and grease, whereas in reality the total quantity of all gas oils and kerosenes (of which the Industry-restricted Gas Oils and Kerosenes are a subset) make up only a fraction of the oil and grease discharged to sewers from such facilities.

7.2.3 Generic product formulation and industrial usage scenario

A generic indirect discharge scenario was used to provide an estimate for exposure resulting from two types of activities: (1) the formulation and/or (2) the industrial application of various products including oil-water separation aids, processing aids, and industrial coatings. The facilities involved with these activities are determined to be indirect dischargers who discharge their treated or untreated wastewater to WWTSs for final treatment before being released to the aquatic environment. This exposure scenario is based upon the largest industrial user of the Industry-restricted Gas Oils and Kerosenes as described below.

The largest industrial user is identified as the facility with the highest combined annual use quantity of the 7 of 42 gas oils and kerosenes included in a CEPA section 71 survey (Environment Canada 2012), including Industry-restricted Gas Oils and Kerosenes, as well as those with uses in products available to consumers . All 26 Industry-restricted Gas Oils and Kerosenes were conservatively assumed to be used by this facility at the same rate as for the 7 gas oils on a per CAS-RN basis. When estimating the use quantity of the Industry-restricted Gas Oils and Kerosenes, the total use quantity of the 7 gas oil CAS RNs was first converted to a per-CAS RN average use quantity. This per-CAS RN average use quantity was then used as an approximation to represent the 26 Industry-restricted Gas Oils and Kerosenes on a per-CAS RN basis. The total use quantity of these 7 gas oils at the largest industrial user was in the range of 1 000 000 to 10 000 000 kg/yr (Environment Canada 2012) and this range's logarithmic average, 3 162 000 kg/yr, was used for the annual use quantity estimate for the 26 Industry-restricted Gas Oils and Kerosenes:

Annual use quantity for the largest industrial user =

$$(3\ 162\ 000 \text{ kg/yr})/7 \times 26 \approx 12\ 000\ 000 \text{ kg/yr}$$

The daily quantity of the Industry-restricted Gas Oils and Kerosenes released to sewer was estimated as 120 kg/d based on an estimated annual operation days of 300 d/yr and an estimated emission factor of 0.3% (ECB 2003). As a conservative assumption, it was assumed there was no on-site WWTS at this facilty. The off-site wastewater treatment removal rate was estimated as 90%, as discussed above. The quantity released to receiving water was estimated as 12 kg/d.

The maximum concentration of the Industry-restricted Gas Oils and Kerosenes in receiving water was estimated by dividing the daily quantity released to receiving water from the WWTS by the daily dilution water volume of the largest industrial user, which is 3 500 million L/d (that is, daily wastewater flow rate x receiving water dilution near discharge point). The aquatic PEC for the indirect discharge scenario was thus estimated to be 3.5 µg/L. This estimate is considered to be conservative because it was assumed there was no on-site wastewater treatment and all 26 CAS RNs of the Industry-restricted Gas Oils and Kerosenes were assumed to be used at a single facility. In reality, it is very likely that on-site wastewater treatment is in place, in particular for large facilities. It is also very likely that any single facility uses only a subset of the 26 CAS RNs rather than all of them, according to the use patterns identified from the information submitted in response to various surveys (Environment Canada 2012, ECCC 2016a, 2016b).

7.2.4 Use of processing aids

Industry-restricted Gas Oils and Kerosenes are present in processing aids used by various types of industrial facilities (Environment Canada 2012, ECCC 2016a,b). They can be grouped under the following four sectors: plastics and rubber, fabricated metal, machinery, and transportation equipment.

To determine the extent of potential exposure from the use of processing aids, the maximum daily quantity of the Industry-restricted Gas Oils and Kerosenes released from an industrial facility to sewer was estimated based on currently available information. A typical limit for the discharge of oil and grease to municipal sewers in Canada (15 mg/L as in the case of Toronto, Ontario (2014)) was assumed to represent the maximum concentration of Industry-restricted Gas Oils and Kerosenes in wastewater released to sewer. The rationale for using a typical sewer limit in Ontario is because the majority of the facilities involved with processing aids containing gas oils and kerosenes are located in Ontario according to information submitted in response to a CEPA section 71 survey (Environment Canada 2012). The use of the sewer limit for oil and grease is a conservative assumption as Industry-restricted Gas Oils and Kerosenes make up only a fraction of the oil and grease discharged from these facilities.

Several datasets were used to determine the average daily wastewater volume discharged from a facility (Table 7-5), including the total annual wastewater volume discharged from the four industrial sectors mentioned above (Statistics Canada 2009), the total number of establishments[10] (Industry Canada 2012), and an estimated number of annual operation days (250 d/yr). This average per-facility discharge volume is approximated by the per-establishment discharge volume.

Daily wastewater discharge volume from a facility

≈ Daily wastewater discharge volume from an establishment

= (Total annual wastewater discharge volume/Number of annual operation days)/Total number of establishments

= (59 600 million L/yr / 250 d/yr)/11 883 facilities

= 20 062 L/d per facility

[10] The term “establishments” is broader than “facilities”. It includes industrial facilities as well as premises such as warehouses and distribution centres (Industry Canada 2012).

Table 7-5. Annual wastewater discharge volumes and number of establishments

Sector	Annual water volume discharged (million L/yr) (Statistics Canada 2009)	Number of establishments (Industry Canada 2012)
Plastics and rubber	24 500	1 761
Fabricated metals	12 600	5 344
Machinery	2 500	3 362
Transportation equipment	20 000	1 416
Total	**59 600**	**11 883**

The maximum daily quantity of Industry-restricted Gas Oils and Kerosenes released from a facility to sewer was estimated as 0.30 kg/d from the daily wastewater discharge from a facility and the sewer limit for oil and grease. The quantity released to receiving water was estimated as 0.03 kg/d by applying the average wastewater treatment removal rate of 90%.

A distribution of PECs, reflecting differences in WWTS effluent flow and receiving water dilution, was determined (Table 7-6). The estimated PEC distribution is very conservative as it is applicable to not only the Industry-restricted Gas Oils and Kerosenes but also to all gas oils and kerosenes with aromatic mass content in the 20%-80% range. In addition, it assumes that Industry-restricted Gas Oils and Kerosenes comprise the entirety of the oil and grease discharged to sewer, whereas in reality the total quantity of all gas oils and kerosenes (of which Industry-restricted Gas Oils and Kerosenes are a subset) make up only a fraction of the oil and grease discharged from such facilities.

Table 7-6. Aquatic PEC distribution for use of processing aids containing Industry-restricted Gas Oils and Kerosenes

Percent of facilities (%)	**Daily dilution water vol. (million L/day)[a]**	**Aquatic PEC (μg/L)**
Minimum	4556	0.007
10	2180	0.01
20	1423	0.02
30	1095	0.03
40	954	0.03
50	484	0.06
60	239	0.1
70	190	0.2
80	106	0.3
90	13.5	2.2
95	7.8	3.8
100	4.8	6.3

[a] The daily dilution water volume is calculated by multiplying the effluent flow of the wastewater treatment system by the dilution factor of the receiving water near the discharge point.

7.2.5 Agricultural soil exposure from biosolids application

Biosolids produced during wastewater treatment may be applied to agricultural fields as a soil amendment. An approach described by the European Chemicals Agency (ECHA 2016) was used to obtain a conservative estimate for the soil exposure to the Industry-restricted Gas Oils and Kerosenes amended to soils (PEC_{soil}, mg/kg).

$$PEC_{soil} = \frac{C_s \times A \times N}{d \times \rho}$$

The amount of the Industry-restricted Gas Oils and Kerosenes was assumed to accumulate over 10 consecutive years (N) within the top 0.2 m (d) layer of soil at a dry soil density of 1200 kg/m^3 (ρ), which is a generic value (Williams 1999). The maximum annual quantity limit for biosolids application in Canada is 0.83 kg/m^2-yr (A) (Alberta Environment 2001). Losses via degradation, volatilization, leaching or soil run-off were assumed to be nil, so estimates for PEC_{soil} are conservative.

The maximum concentration of Industry-restricted Gas Oils and Kerosenes in biosolids (C_s, mg/kg) was estimated based on the maximum quantity of Industry-restricted Gas Oils and Kerosenes (120 kg/d) released to sewer from the largest industrial user as presented in Section 7.2.3. Assuming all removal in the WWTS (90%) was by sludge sorption, the resulting amount in biosolids was determined to be 110 kg/d. The amount of biosolids generated per day was estimated as 36 400 kg/d from the wastewater flow of 350 million L/d associated with the largest industrial user and the average biosolids generation rate of 104 mg per L of wastewater derived from field data of several Canadian secondary WWTS (Kim et al. 2013). C_s was then calculated as 3000 mg/kg (110 kg/d / 36 400 kg/d). The resulting soil PEC is 103 mg/kg dry wt. This estimate is conservative as it is based on a conservative quantity of Industry-restricted Gas Oils and Kerosenes released to sewer and the conservative assumption of no losses from biosolids-amended soil by pathways such as volatilization or leaching.

7.3 Characterization of ecological risk

The approach taken in this ecological assessment was to examine information and develop conclusions using a weight-of-evidence approach and applying precaution to address areas of uncertainty. Evidence was gathered to determine the potential for Industry-restricted Gas Oils and Kerosenes to cause harm in the Canadian environment. Lines of evidence considered include those evaluated in this assessment that support the characterization of ecological risk in the Canadian environment. Reliable secondary or indirect lines of evidence were considered when available, including classifications of hazard or fate characteristics made by other regulatory agencies.

7.3.1 Risk quotient analysis

Risk quotient analyses were performed by comparing the various estimates of exposure (PECs; see the Ecological Exposure Assessment section) with ecotoxicity information (PNECs; see see the Ecological Effects Assessment section) to determine whether there is potential for ecological harm in Canada. Risk quotients (RQs) were calculated by dividing the PEC by the PNEC for relevant environmental compartments and associated exposure scenarios (Table 7-7).

Table 7-7. Summary of risk quotients obtained for exposure scenarios with Industry-restricted Gas Oils and Kerosenes with low and high aromatic content[a]

Exposure scenario (compartment)	PEC or PEC range (µg/L)	PNEC (high (80%) aromatic content) (µg/L)	PNEC (low aromatic content) (µg/L)	RQ or RQ range	Percentage of locations with RQ greater than 1
Formulation of lubricants & additives (water)	3.3	4	14	0.24 - 0.83	0
Generic indirect discharge (water)	3.5	4	14	0.25 - 0.88	0
Use of processing aids (water)	0.007-6.3	4	14	<0.01-1.6	<5 (if high aromatic content) 0 (if low aromatic content)
Biosolids application (soil)	103 mg/kg dw	150 mg/kg dw[b]	150 mg/kg dw[b]	0.7	0

[a] For the kerosene substance that is part of the 26 Industry-restricted gas oils and kerosenes, only the low aromatic content PNEC applies, as well as only the RQ value at the low end of the range, for RQs with ranges.

[b] Based on the Canada-wide Standard for petroleum hydrocarbons greater than C_{10} to C_{16}, with aliphatics:aromatics ratio of 80:20

As shown in Table 7-7, the risk quotients are mainly below one, indicating low potential for ecological harm, with the following exception: a maximum RQ of 1.6 was determined for the use of processing aids scenario. For this scenario, less than 5% of these facilities have RQs slightly greater than one for the high aromatic content scenario only; however, the actual RQs are expected to be lower than one considering that Industry-restricted Gas Oils and Kerosenes make up only a fraction of the oils and greases discharged from these facilities, whereas in the exposure scenario it was conservatively assumed that Industry-restricted Gas Oils and Kerosenes would comprise the entirety of the discharged oils and greases (Section 7.2.5). As well, the exposure scenario is based on usage data for all 42 gas oils and kerosenes prioritized for assessment, rather than on only the 26 Industry-restricted Gas Oils and Kerosenes. The RQs are below one for facilities using lower aromatic content (20%) Industry-restricted Gas Oils and Kerosenes, indicating low concern for these scenarios.

7.3.2 Consideration of the lines of evidence

To characterize the ecological risk of Industry-restricted Gas Oils and Kerosenes, technical information for various lines of evidence was considered (as discussed in the relevant sections of this report) and qualitatively weighted. The key lines of evidence supporting the assessment conclusion are presented in Table 7-8, with an overall discussion of the weight of evidence provided below. The level of confidence refers to the combined influence of data quality and variability, data gaps, causality, plausibility and any extrapolation required within the line of evidence. The relevance refers to the impact the line of evidence has when determining the potential to cause harm in the Canadian environment. Qualifiers used in the analysis ranged from low to high, with the assigned weight having five possible outcomes.

Table 7-8. Weighted lines of key evidence considered to determine the potential for Industry-restricted Gas Oils and Kerosenes to cause harm in the Canadian environment

Line of evidence	Level of confidence[a]	Relevance in assessment[b]	Weight assigned[c]
Persistence in the environment of components of gas oils and kerosenes in water, soil and sediment	high	moderate	moderate to high
Bioaccumulation of components of gas oils and kerosenes in pelagic and mammalian aquatic organisms	high	moderate	moderate to high
PNEC for pelagic aquatic organisms (high aromatic content scenario)	moderate	high	moderate to high
PNEC for pelagic aquatic organisms (low	moderate	high	moderate to high

Line of evidence	Level of confidence[a]	Relevance in assessment[b]	Weight assigned[c]
aromatic content scenario)			
PNEC for soil organisms (low aromatic content scenario)	moderate	high	moderate to high
PNEC for soil organisms (high aromatic content scenario)	moderate	high	moderate to high
PEC (aquatic) for formulation of lubricants and lubricant additives	moderate	high	moderate to high
PEC (aquatic) for generic product formulation and industrial usage	moderate	high	moderate to high
PEC (aquatic) for processing aids	moderate	high	moderate to high
PEC (soil) for biosolids application to agricultural soil	moderate	high	moderate to high
RQ (aquatic) for formulation of lubricants and lubricant additives	moderate	high	moderate to high
RQ (aquatic) for generic product formulation and industrial usage	moderate	high	moderate to high
RQs (aquatic) for processing aids	moderate	high	moderate to high
RQ (soil) for biosolids application to soil, low and high aromatic content scenarios	moderate	high	moderate to high

[a] Level of confidence is determined according to data quality, data variability, data gaps and if the data are fit for purpose.
[b] Relevance refers to the impact of the evidence in the assessment.
[c] Weight is assigned to each line of evidence according to the combined level of confidence and relevance in the assessment.

Weight of evidence for determining potential to cause harm to the Canadian environment

Gas oils and kerosenes contain components (for example, PAHs), that may persist in air and undergo long-range transport to remote regions. They also contain some components that might persist in soil, water and/or sediment, thus increasing the duration of exposure to organisms. The gas oils included in this assessment are also expected to contain components that are highly bioaccumulative, such as PAHs and alkyl-PAHs. Studies suggest that parent PAHs will not likely biomagnify in food webs; however, there is some evidence that alkylated PAHs might. Also, PAHs and alkyl-PAHs may bioaccumulate in aquatic invertebrates, as they lack the capacity to efficiently metabolize aromatic compounds.

The PNECs for aquatic organisms were modelled with PETROTOX (2011) based on the estimated post-wastewater treatment compositions of the gas oils and kerosenes. The PETROTOX chronic modelled data without wastewater treatment are consistent with the limited empirical ecotoxicity data on gas oils and kerosenes, giving confidence in the modelled values. The modelled and empirical chronic NOELRs for low and high aromatic gas oils and kerosenes are mostly less than 0.1 mg/L, indicating that gas oils and kerosenes have high chronic toxicity to aquatic organisms. These substances can persist in water long enough to cause chronic toxicity, and they are released on a continuous basis from industry.

The range of wastewater discharge rates and the average wastewater treatment removal rate of 90% for gas oils and kerosenes are considered to be reliable, as the wastewater discharge rates are consistent with measured Canadian averages, and the modeled removal rate is supported by monitoring data and is consistent with the physical-chemical properties of the gas oils and kerosenes (for example, high log K_{ow} and K_{oc} values of many representative structures). The main unknown for some of these scenarios is the aromatic contents of the gas oils and kerosenes, and for this reason, both low and high aromatic content scenarios were considered in these cases. While it is recognized that Industry-restricted Gas Oils and Kerosenes may be further refined into solvents with smaller carbon ranges and aromatic contents ranging from very low (<2%) to very high (80-100%), an estimate of the toxicity of a solvent relevant to Industry-restricted Gas Oils and Kerosenes indicates that its hazard is less than that of full carbon range Industry-restricted Gas Oils and Kerosenes (Section 7.1.1). Thus, the use of PNECs derived from full carbon range gas oils and kerosenes is considered to provide a conservative estimate of risk for the 26 Industry-restricted Gas Oils and Kerosenes considered in this report (Appendix A), including their use as solvents.

An RQ range of <0.01 to 1.6 was estimated for the scenario involving the use of processing aids (Table 7-7). However, as a result of the conservative assumptions used in this exposure scenario, as described in Section 7.3.1, the maximum RQ of 1.6 is considered to be an overestimate, and the risk to the environment from this use is considered to be low. Additionally, an RQ greater than 1 was only estimated with the high aromatic content scenario, while lower aromatic content Industry-restricted Gas Oils and Kerosenes may often be used.

For all other exposure scenarios, the RQs were below one, indicating low likelihood of risk to the environment at current exposure levels. This information indicates that the 26 Industry-restricted Gas Oils and Kerosenes are not likely to be causing harm to organisms in Canada.

7.3.3 Sensitivity of conclusion to key uncertainties

The composition of Industry-restricted Gas Oils and Kerosenes as defined by the proportions of aliphatic and aromatic chemical classes varies greatly owing to natural compositional differences, as well as the type of processing they have undergone, such that the aromatic content can vary substantially even within one CAS RN. There is uncertainty regarding whether in some industrial facilities, normal variation in a single product from a single supplier would cover a broad range of aromaticity. This is important, as aromatic content influences the toxicity of Industry-restricted Gas Oils and Kerosenes (Section 7.1). To address this uncertainty, the analyses of risk for industrial uses considered a range of aromatic contents, where applicable. However, the lack of information on aromatics content would not affect the outcomes of most of the scenarios (for example, scenario for formulation of lubricants and lubricant additives, general indirect discharge scenario), as the level of risk was found to be low in these scenarios even for gas oils and kerosenes with high aromatics content.

The Canada-Wide Standards for Petroleum Hydrocarbons in Soil (CCME 2008) assume an aromatic to aliphatic ratio of 20:80. As aromatic hydrocarbons have been found to be the primary contributors to toxicity in earthworms (Cermak et al. 2013), the standards are expected to be protective for Industry-restricted Gas Oils and Kerosenes with aromatic contents lower than 20%. For Industry-restricted Gas Oils and Kerosenes with a higher aromatic content, the standards may be less protective. However, given that the soil RQ was less than one, based on the standard for Fraction 2 (greater than C_{10} to C_{16}), which is conservative for gas oils as it represents only the lower, more toxic portion of the carbon range, this uncertainty is not considered to affect the conclusion.

Some components of Industry-restricted Gas Oils and Kerosenes released to water are expected to partition to sediments and may accumulate over time, with some of these components being persistent in sediment. A determination of risk to sediment organisms could not be made due to the lack of information on environmental concentrations in sediment near points of effluent discharge, as well as on the toxicity of Industry-restricted Gas Oils and Kerosenes to organisms through sediment exposure. If this data had been available, it may have added to the lines of evidence which were used to arrive at the conclusion.

The ecological exposure scenarios used conservative assumptions. The exposure scenario for generic product formulation was a conservative scenario for the largest industrial user which was assumed to use all 26 Industry-restricted Gas Oils and Kerosenes together, which is very unlikely (Section 7.2.3). The exposure calculations for the formulation of lubricants (Section 7.2.2) and the use of processing aids (Section 7.2.4) scenarios assumed releases of Industry-restricted Gas Oils and Kersosenes at the sewer discharge limit for oil and grease, when they would be expected to represent only a fraction of the oil and grease discharged from these facilities. Even with these conservative assumptions, most of the RQs showed no risk (that is, were below one). The only RQ range which was partially above one (<0.01 – 1.6) was for the generic product formulation scenario, which was a conservative scenario; additionally, the RQ values above one only apply to a scenario with high (80%) aromatic content, and only when the daily dilution water volume is very low (exceeding the 95^{th} percentile, Table 7-6). The RQs being mostly below one, combined with the conservativeness of the exposure scenarios, strengthens the conclusion that Industry-restricted Gas Oils and Kerosenes are unlikely to be causing ecological harm in Canada.

8. Potential to cause harm to human health

8.1 Exposure assessment

The focus of the human health exposure assessment is to characterize general population exposure to the 26 Industry-restricted Gas Oils and Kerosenes from environmental media. Exposures from petroleum industry-restricted, site-restricted and fuel uses of Gas Oils and Kerosenes have been previously assessed. (Environment Canada, Health Canada 2011, 2013, 2014, 2015). No consumer product uses were identified for substances in this assessment.

8.1.1 Environmental media and food

Industry-restricted Gas Oils and Kerosenes are used in industrial applications as processing aids by plastics and rubber producing facilities, in metal fabrication, in machinery, and in transportation equipment. Unintentional releases of Industry-restricted Gas Oils and Kerosenes may occur at production facilities (for example, petroleum refineries), and during loading, transit, and unloading activities. Industry-restricted Gas Oils and Kerosenes in the industrial water stream are typically subject to wastewater treatment, but residual Industry-restricted Gas Oils and Kerosenes may be released along with post-treatment water into streams, rivers, and lakes. Spills of Industry-restricted Gas Oils and Kerosenes may occur during the transportation of these substances for industrial use. The application of bio-solids containing Industry-restricted Gas Oils and Kerosenes to agricultural lands may also occur. These releases are addressed in Sections 5 and 7. Implications concerning drinking water are discussed in Section 8.3.1

None of the Industry-restricted Gas Oils and Kerosenes are reported to the National Pollutant Release Inventory (NPRI) (NPRI 2020). To determine the effects of potential industrial air releases of the substances in this group and possible inhalation exposure to populations that reside near these facilities, NPRI releases of two other gas oil and kerosene substances (not included in the Industry-restricted Gas Oils and Kerosenes) were considered as representing conservative exposure estimates for those in the current assessment.

SCREEN3, a tier-one air dispersion model developed by the U.S. EPA (SCREEN3 1996),was used to estimate the potential ambient air concentration of gas oils and kerosenes in residential areas that the general population may be exposed to near a hypothetical facility. As none of the substances in this assessment has NPRI reporting data, as a conservative estimate of environmental exposure, the highest estimated concentrations were derived for a facility that released 161 tonnes of the gas oil substance CAS RN 64742-47-8 to air for the 2017 reporting year (NPRI 2022). This was the largest reported release of a gas oil and kerosene substance for a single facility between 2017 to 2020 and is considered a conservative estimate of environmental exposure. Furthermore, none of the non-refinery facilities which use the gas oil and kerosene substances were found to simultaneously release more that a single substance.

Calculations to determine concentration of the released gas oil and kerosene were performed over a range of 10 to 1000 meters from the facility fence line. However, the exposure concentration at a residential area at a distance of 350 m from the industrial release site was considered, as this is typical of distances of residential areas from fence lines of industrial facilities of this kind. Using the release rate and exposure factors given in Table B-1 of Appendix B, the annual average ambient air concentration for a gas oil and kerosene substance resulting from facility releases to air at a distance of 350 m was estimated to be 0.27 mg/m^3. This concentration represents a potential dose of 0.055 (adults 19+) – 0.16 mg/kg bw/day (infants, 1 yr), assuming complete inhalation absorption.

As these substances are not present in food packaging and/or incidental additives, exposures via this route are not expected.

8.2 Health effects assessment

Industry-restricted Gas Oils and Kerosenes share similar physical-chemical properties, depending on processing steps, level of refinement and identity of blending streams, and can therefore have similar toxicological properties.

In the present document, 26 CAS RNs for Industry-restricted Gas Oils and Kerosenes were assessed. Health effects information regarding some of these substances was limited. However, all the available information on substances that are considered similar to those gas oils and kerosenes for which there are potential human exposures were taken into account. This includes the data in the screening assessment reports on other gas oils, fuel oil No. 2, aviation fuels (for example, Jet-A and kerosene) (Environment Canada, Health Canada 2011, 2013, 2014, 2015). Toxicological studies of diesel fuel are also considered. A summary of key toxicity studies based on this broader group of gas oils and kerosenes is outlined below.

Repeated dose toxicity

Short-term (14-day) repeat-dose (7 days/week) dermal application of a gas oil (JP-5 fuel) at 0, 5000, 10 000, 20 000, 30 000 or 40 000 mg/kg-bw/d (in 95% ethanol) caused irritation, hair loss, and acanthosis or inflammation at the site of application (shaved back) at all doses in male or female mice. All mice died in the 40 000 mg/kg-bw/d dose group (n=10) and only female mice died (5/5) in the 30 000 mg/kg-bw/day group before study termination. A no-observed-adverse-effect level (NOAEL) of 5000 and a lowest-observed-adverse-effect level (LOAEL) of 10 000 mg/kg-bw/d was determined by the study authors based on decreases in body weight in both sexes (NTP 1986).

Repeat-dose dermal exposure for 14 days (5 d/wk) was reported to cause anorexia, depression and severe skin damage at the treatment area following application of 6400 mg/kg bw/d (only one dose reported) of Jet fuel A in rabbits (API 1980, API 2010).

A 21 day dermal study of diesel fuel #2 on rabbits was reported (IITRI 1984, API 2012a,b). The substance was applied to rabbit skin (shorn) at 200, 670 or 2000 mg/kg-bw/day), once a day, 5 days/wk. Exposure at all doses caused minimal skin irritation after first exposure, however, increasing skin irritation and hair loss as the treatments progressed was noted. Moreover, the clinical signs following exposure to diesel fuel were reported to be related to the degree of skin irritation (API 2012a). The highest dose (2000 mg/kg-bw/day) caused mortality in 2/10 female and 1/10 male rabbits. The authors determined the study LOAEL to be 200 mg/kg-bw/day based on decreased mean corpuscular hemoglobin concentration, which was observed in conjunction with severe dermal irritation.

In a 28-day study (API 1985), dermal exposure to undiluted kerosene at 0, 200, 1000 or 2000 mg/kg-bw/d, (3 times/week) caused skin irritation in male and female rabbits, decreased blood cell count in males and increased absolute and relative spleen weight in female rabbits. The authors concluded that hematological, biochemical or histopathological changes seen in male rats were not treatment related or were secondary to skin irritation or incidental weight changes (API 1985, API 2010). However, the US EPA identified a LOAEL of 200 mg/kg-bw based on skin irritation in both sexes and decrease in RBCs and increase in spleen weight in female rats (USEPA 2006). Treatment-related clinical signs reported in API (2010) included thinness, lethargy, wheezing, and nasal and anal discharge in both sexes (API 1985, API 2010a,b).

Subchronic (90-day) exposure to undiluted JP-8 fuel at 0, 750, 1500 or 3000 mg/kg-bw/d by gavage in male Sprague-Dawley rats caused a dose-dependent decrease in body weight at 6%, 13%, or 43%, respectively with respect to controls. An increase in liver, spleen and testes weight was seen in the highest dose group but no histopathological changes were observed (Mattie 1995). A LOAEL of 750 mg/kg-bw/d was identified by the US EPA based on decrease in body weight, increase in relative liver weight and increase in total bilirubin (US EPA 2011b).

In a 90-day dermal repeat-dose study, application of hydrodesulfurized (HSD) kerosene for 6 hr/d, 5 d/wk on shaved back skin did not cause systemic or neurotoxicity toxicity in male or female rats at dose of 0, 165, 330 or 495 mg/kg-bw/d (Breglia 2014). The only dose-related change was minimal skin irritation at the application site, which was completely reversible in both sexes within 4 week. The highest dose (495 mg/kg-bw/d) was considered as the NOAEL for neurotoxicity by study authors based on the absence of effects on the central or peripheral nervous system and lack of neurological signs (Breglia 2014). Repeated dermal exposure to kerosenes cause local irritation or defatting which leads to dermatitis in many animal models following repeated exposure. The degree of irritation is dependent on the substance type, dose and duration of exposure. However, there is no evidence to support that single low dose exposure to kerosene causes adverse systemic effects (CONCAWE 2017, 1999; API 2010).

Subchronic (28-day) inhalation exposure (6 hr/d for 5 days/week) to nominal dose of 24 mg/m^3 of hydrodesulfurized kerosene did not cause any physiological, haematological, or histological changes in males or female SD rats as reported by study authors (API 1986, API 2010). The NOAELs for local or systemic effects were reported > 24 mg/m^3 for kerosene in API (2010 a,b).

In another study, no significant changes were observed by study authors in spleen or thymus weight and no adverse effects were seen on the cells of functional immune system following inhalation exposure to 0, 500, 100 or 2000 mg/m^3 of jet fuel kerosene for 28 days (6 hr/d) in female rats or mice at any dose (White 2013).

Reproductive or Developmental toxicity

In a reproductive and developmental study, dermal application (1 mL/kg) of 165, 330 or 494 mg/kg-bw/d of kerosene for 7 weeks during 14 days premating and mating to GD19 in females and 8 week in males did not cause maternal, reproductive, or developmental toxicity in male or female rats. The highest dose (494 mg/kg-bw/d) was reported as NOAEL by the authors (Schreiner 1997).

In a dermal exposure study, pregnant rats were applied with 0, 25, 50, 125, 250 or 500 mg/kg of light cycle oil, a kerosene substance, on shaved back from GD 0-19 (Mobil 1988b, API 2012b). A dose of 1000 mg/kg-bw/d was applied either from GD 0-6 or GD 6-15 due to severe irritation at onset of treatment. All dams showed erythema and flaking of skin at all doses. A LOAEL of 1000 mg/kg-bw/d was reported by API for developmental toxicity based on statistically significant decreased fetal body weights (API 2012b). The available 4-week dermal studies have shown slight to moderate skin irritation following exposure to gas oils; however, no significant adverse effects were reported on the reproductive system in rats (API 2010a,b).

In an inhalation developmental study, exposure to kerosene at 106 or 364 ppm (~737 or 2530 mg/m^3) for 6 hr/d from GD 6-15 in pregnant female SD rats did not cause any adverse developmental effects in the offspring, as reported by study authors. A maternal or teratogen NOAEL of 364 ppm (2530 mg/m^3) was reported in this study (API 1979a, cited in API 2012b, 2010b). Similarly, in another developmental study, inhalation exposure to Jet Fuel A at 102.5 or 394.7 ppm (~712 or 2744 mg/m^3) in pregnant female SD rats for 6 hr/d through GD 6-15 did not report adverse effects on fetal growth or development and it was not considered teratogenic by study authors. A maternal or teratogenic NOAEL of 394.7 ppm (2744 mg/m^3) was reported in this study (API 1979b, API 2012b, 2010b).

In another developmental study, oral (gavage) exposure to 0, 500, 1000, 1500 or 2000 mg/kg-bw/d of JP-8 fuel on GD 6-15 (once/day) caused 31%, 70% or 85% reduction in body weight gain in the 1000, 1500, and 2000 mg/kg-bw/d dose groups, respectively, in pregnant rats. A decrease in fetal body weight was observed in males (15%) and females (13%) in the 1500 mg/kg-bw/d dose group (Cooper and Mattie 1996, US EPA Chemview 2018; US EPA 2011). A developmental LOAEL of 1500 and a NOAEL of 1000 mg/kg-bw/d was reported in US EPA Chemview (2018) based on decrease in fetal body weight. Moreover, the 500 mg/kg-bw/d dose was considered as the NOAEL for maternal toxicity (US EPA Chemview 2018; US EPA 2011).

Carcinogenicity

Three of the Industry-restricted Gas Oil and Kerosene substances are classified as Category 1B “may cause cancer” (Table C-1 Appendix C) (European Commission 2008, ECHA 2012). However, the European commission (Regulation EC No. 1272/2008, Annex VI) states the classification as a 1B carcinogen does not apply to these gas oils if the refining history is known and the substance(s) from which they are produced can be shown to not be carcinogenic. This is typically demonstrated by containing less than 0.1% individual carcinogens and/or less than 3 wt% DMSO extractable total PAH/aromatic content (European Commission 2004, Clark et al. 2013, CONCAWE 2012).

In a 2-year dermal exposure study, application of marine diesel fuel or JP-5 at 250 or 500 mg/kg-bw provided no evidence of carcinogenicity in male or female mice (NTP 1986). Several dermal exposure studies have shown that repeated long-term exposure to petroleum middle distillates (PMD) including HSD kerosene may produce skin tumors in mice only after sustained severe dermal irritation through nongenotoxic mechanism as a result of frequent cell damage and repair over a long time (Freeman et al. 1993; Freeman and McKee 1993; Ingram 1993; Nessel 1998; Walborg 1998). If these substances are applied to skin in a manner that did not cause skin irritation (for example, diluted with mineral oil), the tumorigenic activity were reported by study authors to not occur (API 2010; CONCAWE 1996b).

***In vitro* and *in vivo* genotoxicity**

Gas Oils and Kerosenes have demonstrated genotoxic potential in *in vitro* and *in vivo* assays of genetic toxicity, although results are mixed depending on substance and assay type. Results from multiple assays have been reviewed in previous gas oil screening assessments (Environment Canada Health Canada 2011, 2013, 2015).

Using a modification of the standard bacterial reverse mutation *Salmonella* test, API reported that there was a high correlation between mutagenic activity and wt% DMSO extractable PAC in base oils, with activity noted at 3 wt% DMSO extractable PAC and above (API 2012a). The modified assays were different from the standard assay in three ways. The first was the tests were performed on the DMSO extractable fraction only. The second was to use S-9 from aroclor-induced hamster liver at eight times the recommended concentration, and lastly was the exclusive use of TA98, the tester strain most responsive to complex mixtures of PAC (API 2012a; Chasey 1993).

Similar to base oils, the genotoxicity potential of the Industry-restricted Gas Oils and Kerosenes is related to their PAH content, with increasing PAH content associated with increasing genotoxicity (API 2013b).

Epidemiology studies

A limited number of studies in humans, including case reports and studies conducted on volunteers, were identified for gas oils. One case report describes substantial and prolonged dermal exposure to ‘diesel oil’, where it was used over several weeks as an arm and hand cleaner. Development of epigastric and loin pains, nausea, anorexia, degeneration of kidney tubular epithelium and reversible renal failure were observed (Crisp et al. 1979). With respect to occupational exposures to diesel fuels, a case-control study of male cancer patients revealed a combined adjusted odds ratio of 1.9 (90% confidence interval = 1.2-3.0) for prostate cancer in men with non-substantial or substantial exposures to diesel fuel. However, the authors noted there is no evidence of a positive dose-response relationship in this study, and the results are confounded by exposures to other petroleum substances and unknown routes of exposure (Siemiatycki 1987). Long-term dermal occupational exposures to kerosene (for 5 hr/d, dose not known) produced dermatosis and erythema in factory workers (Jee 1985, ATSDR 1995b). However, no studies were found to show the ability of fuel oils to cause hepatic, musculoskeletal, reproductive, developmental, or immunological effects following dermal exposure in humans (ATSDR 1995b).

Human Volunteer Studies

The irritant properties of diesel fuels have been assessed in studies of short-term dermal exposures of human volunteers. No visible skin effects were seen after 15 minutes of dermal exposure to 1.5 mL (approximately 18 mg/kg-bw) of six diesel fuel samples over an area of 3.1 cm^2; however, a slight increase in blood flow to the area was reported in some cases (Wahlberg 1995). Another dermal study in human volunteers observed increased skin irritancy with cumulative exposure time, when diesel fuel samples were applied for time points ranging from 15 minutes to 48 hours. Irritation was first reported after 4 hours of exposure. Occlusion of the application site and the application of ‘newer’ (that is, lower sulphur and aromatic content) blends of diesel fuels (samples MK I and MK II) produced greater irritancy (Fischer and Bjarnason 1996).

8.3 Characterization of risk to human health

8.3.1 Exposure from environmental media

Potential risks to the general population from possible exposure to gas oils from their production, use, and transport between petroleum facilities have been previously addressed (Environment Canada Health Canada 2013). The maximum yearly average exposure via inhalation for the gas oil (64742-47-8) for the general population living in the vicinity of a non-petroleum facility using gas oils was 0.055 (adults 19+) – 0.16 mg/kg bw/day (infants, 1 yr), assuming complete inhalation absorption. Compared to the 90 day subchronic oral LOAEL of 750 mg/kg-bw/day for decrease in body weight and increase in liver, spleen, and testes weight (Mattie 1995), these exposures give a margin or exposure (MOE) of 4700 – 13 600. The MOEs are considered adequate to address the uncertainty in the available hazard and exposure data and therefore the risk to the general population in Canada from inhalation exposure to gas oil and kerosene substances from non-petroleum industrial facilities is considered to be low.

As described in Section 8.1.1, there is the potential for Industry-restricted Gas Oils and Kerosenes to be released to water bodies via wastewater releases. There is a potential for exposure if these substances are released into water bodies that become a source of drinking water. Of particular concern would be if any of these Industry-restricted Gas Oils and Kerosenes contained PAH or BTEX components. Canadian Federal guidelines and provincial / municipal regulations are in place for both industrial discharges to water, and for drinking water itself, for many potential components of Industry-restricted Gas Oils and Kerosenes, including PAHs and BTEX. Examples of some of these at the federal, provincial and municipal level include: (CCME 1999; CCME 2004 a,b,c,d; CCME 2008; Ontario 1994; Ontario 2017; Ottawa 2011; Ottawa 2018). It is expected that after being processed through a drinking water treatment facility, that any water intended for consumption, showering, or bathing will not contain gas oil and kerosene components at a level that would be considered to be of concern for human health.

The human health assessment took into consideration those groups of individuals within the Canadian population who, due to greater susceptibility or greater exposure, may be more vulnerable to experiencing adverse health effects. Subpopulations living near non-petroleum industrial facilities using gas oils and kerosenes who may have potential for higher exposures from emissions in the air were considered in the assessment.

8.4 Uncertainties in evaluation of risk to human health

There is a lack of specific hazard data for many of the gas oil and kerosene substances of this assessment. Substances that are more data rich such as kerosene, jet fuel and diesel fuel are considered to be representative of the Industry-restricted gas oils and kerosenes. There is also a lack of information on environmental media exposures to Industry-restricted Gas Oils and Kerosenes.

The application of biosolids containing Industry-restricted Gas Oils and Kerosenes to agricultural land was not evaluated, but is not expected to be a significant source of exposure to the general population. There is, however, a lack of data on this source of exposure.

9. Conclusion

Considering all available lines of evidence presented in this assessment, there is low risk of harm to the environment from the 26 Industry-restricted Gas Oils and Kerosenes in this assessment. It is concluded that the 26 Industry-restricted Gas Oils and Kerosenes in this assessment do not meet the criteria under paragraphs 64(*a*) or 64*(b)* of CEPA as they are not entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity or that constitute or may constitute a danger to the environment on which life depends.

Considering all the information presented in this assessment, it is concluded that the 26 Industry-restricted Gas Oils and Kerosenes in this assessment do not meet the criteria under paragraph 64(*c*) of CEPA as they are not entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger in Canada to human life or health.

Therefore, it is concluded that the 26 Industry-restricted Gas Oils and Kerosenes in this assessment do not meet any of the criteria set out in section 64 of CEPA.

References

Adam G, Duncan HG. 1999. Effect of diesel fuel on growth of selected plant species. Environ Geochem Health. 21:353-357.

Air Force. 1989. The installation restoration program toxicology guide: Volume 4. Contract no. 1891-A076-Al. Wright Patterson Air Force Base, OH: Harry G. Armstrong Aerospace Medical Research Laboratory, Aerospace Medical Division, Air Force Systems Command. DOE Interagency Agreement No. 1891-A076-Al. [cited in ATSDR 1995b].

Alberta Environment. 2001. Guidelines for the application of municipal wastewater sludges to agricultural lands (updated 2009). Edmonton (Alberta): Alberta Environment. [accessed August 19, 2021].

Altgelt K, Boduszynski M. 1994. Composition and Analysis of Heavy Fractions, Marcel Dekker, Inc. [cited in API 2012a]

Andersen I, Lundqvist GR, Milhave L, Pedersen OF, Proctor DF, Vaeth M, Wyon DP. 1983. Human exposure to controlled levels of toluene in six-hour exposures. Scand J Work Environ Health. 9:405-418.

[API] American Petroleum Institute. 1979. Teratology study in rats, diesel fuel. API Med Res Publ. 27-32174, Washington D.C.

[API] American Petroleum Institute. 1980. Acute toxicity tests on API 79-6, diesel fuel (market-place sample). Primary dermal irritation. Primary eye irritation. Skin sensitization. Acute dermal toxicity. Acute oral toxicity. Subacute dermal toxicity. Study conducted by Elars Bioresearch Laboratories Inc. Report No. 27-32817. Washington (DC): API. [cited in API 2003; ECB 2000b; CONCAWE 1996b].

1985. Acute oral toxicity study in rats. Acute dermal toxicity study in rabbits. Primary dermal irritation study in rabbits. Primary eye irritation study in rabbits. Dermal sensitization study in guinea pigs. API 83-09 straight run kerosine (CAS 8008-20-6). HESD Res. Publ. No. 32-32858 [cited in API 2003].

[API] American Petroleum Institute. 1986. Four-week subchronic inhalation toxicity study in rats: Final report API 81-07, hydrodesulfurized kerosine (petroleum) (CAS 64742-81-0). API 81-09, hydro-desulfurized middle distillate (petroleum) (CAS 64742-80-9). API 81-10, hydro-desulfurized middle distillate (petroleum) (CAS 64742-80-9). API Med Res Publ. 33-32724, Washington D.C.

[API] American Petroleum Institute. 2003. Robust summary of information on kerosene/jet fuel. Report No. 201-15020B. American Petroleum Institute.

[API] American Petroleum Institute. 2010a. High Production Volume (HPV) Chemical Challenge Program. Kerosene/Jet Fuel Category Analysis Assessment Document. Washington (DC): American Petroleum Institute.

[API] American Petroleum Institute. 2010b. Robust summary of information on kerosene/jet fuel. Consortium Registration #1100997. Updated September 2010. American Petroleum Institute.[accessed 2017 July]

[API] American Petroleum Institute. 2012a. High Production Volume (HPV) Chemical Challenge Program. Gas Oils Category Analysis Document and Hazard Characterization. Washington (DC): American Petroleum Institute. [accessed 2019 April 11]

[API] American Petroleum Institute. 2012b. Robust summary of information on Gas Oils. Consortium Registration #1100997. Updated Oct. 23, 2012, 363 pp. [accessed 2019 April 11]

[API] American Petroleum Institute. 2012c. Product composition of hydrodesulfurized kerosene, CAS RN 64742-81-0.

[API] American Petroleum Institute. 2013a. Product composition of light catalytic cracked gas oil, CAS RN 64741-59-9.

[API] American Petroleum Institute. 2013b. Gas Oils Category Analysis Document and Hazard Characterization. [accessed 2018 April 17]

[API] American Petroleum Institute. 2014a. Gas Oils Analytical Data (spreadsheet). March 26, 2014 [accessed 1 June 2017].

[API] American Petroleum Institute. 2014b. Kerosene-Jet Fuel Analytical Data (spreadsheet). March 26, 2014 [accessed 1 June 2017].

Arnot JA, Gobas FA. 2003. A generic QSAR for assessing the bioaccumulation potential of organic chemicals in aquatic food webs. QSAR Comb Sci 22: 337-345.

Arthurs P, Stiver WH, Zytner RG. 1995. Passive volatilization of gasoline from soil. J Soil Contam. 4:1-13

Atlas, MR. 1981. Microbial degradation of petroleum hydrocarbons: an environmental perspective. Microbiol Rev 45:180-209.

[ATSDR] Agency for Toxic Substances and Disease Registry 1995a. Toxicological profile for polycyclic aromatic hydrocarbons. U.S. Department of Health and Human Services.

[ATSDR] Agency for Toxic Substances and Disease Registry. 1995b. Toxicological profile for Fuel Oils. Atlanta (GA): U.S. Department of Health and Human Services, Public Health Service. [cited 2017 Oct 10].

Banerjee S. 1984. Solubility of organic mixtures in water. Environ Sci Technol 18: 587–591.

Bott T, Rogenmuser K. 1978. Effects of no. 2 fuel oil, Nigerian crude oil, and used crankcase oil on attached algal communities: acute and chronic toxicity of water-soluble constituents. Appl Environ Microbiol 36: 673-682.

Breglia R, Bui Q, Burnett D, Koschier F, Lapadula E, Podhasky P, Schreiner C, White R. 2014. A 13-week dermal repeat-dose neurotoxicity study of hydrodesulfurized kerosene in rats. Int J Toxicol 33 (Suppl 1): 685-775.

British Columbia. 2017. Past Spill Incidents, Incident Overviews April 2016 – Earlier. [accessed 11 Apr. 2017]

Brost EJ, DeVaull GE. 2000. Non-aqueous phase liquid (NAPL) mobility limits in soil. In: API Soil and Groundwater Research Bulletin No. 9. Washington (DC): American Petroleum Institute.

Canada. 1999. *Canadian Environmental Protection Act, 1999*. S.C., 1999, c. 33. *Canada Gazette*, Part III, vol. 22, No. 3.

Cappaert NLM, Klis SFL, Baretta AB, Muijser H, Smoorenburg GF. 2000. Ethyl benzene-induced ototoxicity in rats: A dose-dependent mid-frequency hearing loss. JARO 01: 292-299.

[CCME] Canadian Council of Ministers of the Environment. 1999. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Polycyclic Aromatic Hydrocarbons (PAHs). Hull, Quebec.

[CCME] Canadian Council of Ministers of the Environment. 2004a. Canadian soil quality guidelines for the protection of environmental and human health: Benzene (2004). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg. [accessed 2017, November 16].

[CCME] Canadian Council of Ministers of the Environment. 2004b. Canadian soil quality guidelines for the protection of environmental and human health: Toluene (2004). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg. [accessed 2017, November 16].

[CCME] Canadian Council of Ministers of the Environment. 2004c. Canadian soil quality guidelines for the protection of environmental and human health: Ethylbenzene (2004). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg. [accessed 2017, November 16].

[CCME] Canadian Council of Ministers of the Environment. 2004d. Canadian soil quality guidelines for the protection of environmental and human health: Xylenes (2004). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg. [accessed 2017 November 16]

[CCME] Canadian Council of Ministers of the Environment. 2008. Canada-wide standards for petroleum hydrocarbons (PHC) in soil: scientific rationale. Supporting technical document. Winnipeg (MB): Canadian Council of Ministers of the Environment. Report No.: PN 1399. [accessed 2019 April 11]

Cermak JH, Stephenson GL, Birkholz D, Dixon DG. 2013. Investigation of the toxicokinetics of petroleum hydrocarbon distillates with the earthworm *Eisenia andrei*. Environ Toxicol Chem 32:1006-1015.

Chasey KL, McKee RH. 1993. Evaluation of the dermal carcinogenicity of lubricant base oils by the mouse skin painting bioassay and other proposed methods. J Appl Toxicol 13:57-65.

Clark CR, McKee RH, Freeman JJ, Swick D, Mahagaokar S, Pigram G, Roberts LG, Smulders CJ, Beatty PW. 2013. A GHS-consistent approach to health hazard classification of petroleum substances, a class of UVCB substances. Reg. Toxicol. Pharmacol. 67: 409-420.

[CONCAWE] Conservation of Clean Air and Water in Europe. 1995. Kerosines/jet fuels. Prepared by CONCAWE's Petroleum Products and Health Management Groups. Brussels (BE): CONCAWE. Product Dossier No. 94/106. 45 pp.

[CONCAWE] Conservation of Clean Air and Water in Europe. 1996a. Gas oils (diesel fuels/heating oils). Prepared by CONCAWE's Petroleum Products and Health Management Groups. Brussels (BE): CONCAWE. Product Dossier No. 95/107. 66 p.

[CONCAWE] Conservation of Clean Air and Water in Europe. 1996b. Overview of the CONCAWE middle distillate programme. Prepared by CONCAWE's Toxicology Subgroup for the Health Management Group. Brussels (BE): CONCAWE. Report No. 96/62. [accessed 2017, July]

[CONCAWE] Conservation of Clean Air and Water in Europe. 1996c. Environmental risk assessment of petroleum substances: hydrocarbon block method. CONCAWE Report No. 96/52. Prepared by members of CONCAWE's Petroleum Products Ecology Group (King DJ, Lyne RL, Girling A, Peterson DR, Stephenson R and Short D). Brussels (Belgium): CONCAWE.

[CONCAWE] Conservation of Clean Air and Water in Europe. 2012. REACH – Analytical characterisation of petroleum UVCB substances. Brussels (BE): CONCAWE, Analytical Information Task Force. Report No.: 7/12.

Cooper JR, Mattie DR. 1996. Developmental toxicity of JP-8 jet fuel in the rat. J Appl Toxicol. 16(3):197-200.

Crisp AJ, Bhalla AK, Hoffbrand BI. 1979. Acute tubular necrosis after exposure to diesel oil. Brit Med J 2: 177.

Di Toro DM, McGrath JA, Stubblefield WA. 2007. Predicting the toxicity of neat and weathered crude oil: toxic potential and the toxicity of saturated mixtures. Environ Tox Chem. 26:24-36.

Dow RL. 1978. Size-selective mortalities of clams in an oil spill site. Mar Poll Bull 9:45-48 [cited in CONCAWE 1995].

[EC] European Commission. 2004**.** Commission Directive 2004/93/EC of 21 September 2004 amending Council Directive 76/768/EEC for the purpose of adapting its Annexes II and II to technical progress. Official Journal of the European Union. 25.9.2004. L 300, Vol. 13. [accessed 2019 April 11]

[EC] European Commission. 2008. Details on substances classified in Annex VI to Regulation (EC) No 1272/2008 [Database on the Internet]. Ispra (IT): European Commission, Joint Research Centre, Institute for Health and Consumer Protection. [cited 2014] [accessed 2019 April 11]

[ECB] European Chemicals Bureau. 2000a IUCLID dataset for distillates (petroleum), hydrotreated middle, CAS RN 64742-46-7. European Chemicals Bureau, European Commission.

[ECB] European Chemicals Bureau. 2000b. IUCLID dataset for distillates (petroleum), solvent-refined middle, CAS RN 64741-91-9. European Chemicals Bureau, European Commission.

[ECB] European Chemicals Bureau. 2000c. IUCLID dataset for distillates (petroleum) acid-treated middle, CAS RN 64742-13-8. European Chemicals Bureau, European Commission.

[ECB] European Chemicals Bureau. 2000d. IUCLID dataset for gas oils (petroleum), hydrodesulfurized, CAS RN 64742-79-6. European Chemicals Bureau, European Commission.

[ECB] European Chemicals Bureau. 2000e. IUCLID dataset for distillates (petroleum), light hydrocracked, CAS RN 64741-77-1. European Chemicals Bureau, European Commission.

[ECB] European Chemicals Bureau. 2003. Technical guidance document on risk assessment in support of Commission Directive 93/67/EEC on risk assessment for new notified substances and Commission Regulation (EC) No 1488/94 on risk assessment for existing substances. Luxembourg City (LU): European Chemicals Bureau.

[ECCC] Environment and Climate Change Canada. 2016a. Report of data collected under the Canadian Environmental Protection Act, 1999. Notice with respect to certain priority petroleum substances on the

Domestic Substances List. Canada Gazette, Part I, Vol. 149, no. 30. July 25, 2015. pp. 1979-1991. Report prepared by: Environment Canada, Oil, Gas, and Alternative Energy Division, 7 Oct 2016.

[ECCC] Environment and Climate Change Canada. 2016b. Report of data on petroleum substances collected by voluntary data gathering initiative. Data prepared by: Environment Canada, Health Canada; Existing Substances Program, 24 Nov. 2016. [ECCC]

Environment and Climate Change Canada. 2022. Supporting Documentation: Effects and Other Data. Gatineau (QC): Information in support of the Draft Screening Assessment for Gas Oils and Kerosenes. Available from: substances@ec.gc.ca.

[ECCC, HC] Environment and Climate Change Canada, Health Canada. 2011. Screening Assessment. Petroleum Sector Stream Approach. Gas Oil [site restricted], CAS RN 68333-25-5. Health Canada, Ottawa. [accessed 2020 March 16]

[ECCC, HC] Environment and Climate Change Canada, Health Canada. 2016. Screening assessment report. Ethylbenzene. Health Canada, Ottawa. [accessed 2018 March 16]

[ECCC, HC] Environment and Climate Change Canada, Health Canada. [modified 2017 Mar 12]. Categorization. Ottawa (ON): Government of Canada. [accessed 2021 07 21].

[ECHA] European Chemicals Agency. 2012. CMR Substances from Annex VI of the CLP Regulation. Annex I. Helsinki, Finland. [accessed 2017 October 4]

[ECHA] European Chemicals Agency. 2016. Guidance on information requirements and chemical safety assessment. Chapter R.16: Environmental exposure estimation, version 3.0. Helsinki (FI): ECHA.

Environment Canada. 2011. *Canadian Environmental Protection Act, 1999*, Section 71: Notice with respect to certain high priority petroleum substances on the *Domestic Substances List*. Canada Gazette, Part I, Vol. 145, no. 51. Dec. 17, 2011. pp. 3740–3762. [accessed 2017 October 24]

Environment Canada. 2012. Data collected under the *Canadian Environmental Protection Act, 1999*, section 71: Notice with respect to certain high priority petroleum substances on the Domestic Substances List, Part I, Vol. 145, no. 51. Dec. 17, 2011. pp. 3740–3762. Data prepared by: Environment Canada, Health Canada; Existing Substances Program.

Environment Canada. 2013. Operation data of major Canadian lubricant producers. Environmental Stewardship Branch, Gatineau, Quebec.

Environment Canada. 2014. Technical document on the persistence and bioaccumulation potential of petroleum hydrocarbons. Gatineau (QC): Ecological Assessment Division, Environment Canada. Available on request from substances@ec.gc.ca.

Environment Canada. 2015. *Canadian Environmental Protection Act, 1999*. Notice with respect to certain priority petroleum substances on the *Domestic Substances List*. Canada Gazette, Part I, Vol. 149, no. 30. July 25, 2015. pp. 1979-1991.

Environment Canada, Health Canada. 1993. Priority Substance List Assessment Report. 1993. Benzene. Government of Canada, Environment Canada, Health Canada. Ottawa, ON. [accessed 2018 May 10]

Environment Canada, Health Canada. 1994. Priority Substances List Assessment Report, Polycyclic Aromatic Hydrocarbons. Ottawa (ON). [accessed 2018 April 9]

Environment Canada, Health Canada. 2011. Screening Assessment, Petroleum Sector Stream Approach: Gas Oil [Site-Restricted], CAS RN 68333-25-5. Ottawa (ON): Environment Canada, Health Canada.

Environment Canada, Health Canada. 2013. Final Screening Assessment for the Petroleum Sector Stream Approach: Stream 2 Gas Oils; Industry restricted. Ottawa (ON): Environment Canada, Health Canada.

Environment Canada, Health Canada. 2014. Final Screening Assessment, Petroleum Sector Stream Approach: Aviation Fuels [Fuels], CAS RNs 64741-86-2, 64741-87-3, 64741-27-5. Ottawa (ON): Environment Canada, Health Canada.

Environment Canada, Health Canada. 2015. Screening Assessment for the Petroleum Sector Stream Approach: Stream 3 Fuel Oil No. 2; Fuels. Ottawa (ON): Environment Canada, Health Canada. [accessed 2018 March 16]

[EPI Suite] Estimation Programs Interface Suite for Microsoft Windws [Estimation Model]. 2008. Version 3.4. Washington (DC): US Environmental Protection Agency, Office of Pollution Prevention and Toxics; Syracuse (NY): Syracuse Research Corporation.[accessed 2017 Nov 24]

Fischer T, Bjarnason B. 1996. Sensitizing and irritant properties of 3 environmental classes of diesel oil and their indicator dyes. Contact Dermatitis 34:309-315.

Freeman JJ, Federici TM, McKee RH. 1993. Evaluation of the contribution of chronic skin irritation and selected compositional parameters to the tumorigenicity of petroleum middle distillates in mouse skin. Toxicology 81:103-112.

Freeman J, McKee R. 1993. The objectives and goals of dermal carcinogenicity testing of petroleum liquids. In: Health Risk Assessment. Dermal and Inhalation Exposure and Absorption of Toxicants. R. Wang, J. Knaak and H. Maibach, eds., CRC Press, Boca Raton, Fl. pp. 283-290.

Grassle JF, Elmgren R, Grassle JP. 1981. Response of benthic communities in MERL experimental ecosystems to low level, chronic additions of No. 2 fuel oil. Mar Environ Res 4: 279-297.

Hamoutene D, Payne JF, Andrews C, Wells J, Guiney J. 2004. Effects of a synthetic drilling fluid (IPAR) on antioxidant enzyme and peroxisome proliferation in the American lobster, *Homarsus americanus.* Can Tech Rep Fish Aquat Sci No. 2554. Ottawa (ON): Department of Fisheries and Oceans.

Harris KA, Nichol LM, Ross PS. 2011. Hydrocarbon concentrations and patterns in free-ranging sea otters (*Enhydra lutris*) from British Columbia, Canada. Environ Toxicol Chem 30: 2184-2193.

Health Canada. 1998. Exposure Factors for Assessing Total Daily Intake of Priority Substances by the General Population of Canada. Health Canada, Environmental Health Directorate, Bureau of Chemical Hazards.

Health Canada. 2015. Guidelines for Canadian Drinking Water Quality. Toluene, Ethylbenzene and the Xylenes. Technical Document. Government of Canada. Ottawa. [accessed 2018 March 16]

Health Canada. 2016. Guidelines for Canadian Drinking Water Quality. Benzo[a]-pyrene. Technical Document. Government of Canada. Ottawa. [accessed 2020 September 8]

Health Canada. 2017. Product Safety Testing. Chemistry Methods. Health Canada. [accessed 2017 October 2]

Household Products Database. 2016. U.S. Department of Health and Human Services, Bethesda, MD. [accessed 2017 September 22]

[HSPA] Hydrocarbon Solvents Producers Association. 2018. Hydrocarbon Solvents REACH Registrations, CAS-EC number relationship. [Accessed 13 Feb 2020].

[IITRI] IIT Research Institute. 1984. Three week percutaneous toxicity study of diesel fuel in rabbits. Final report. IITRI Project No. L8100. Study sponsored by Standard Oil Co. (Indiana). Chicago (IL): IIT Research Institute. [cited in API 2003].

Industry Canada. 2012. Canadian industry statistics. Canadian Business Patterns Database, December 2012. Statistics for plastics and rubber, fabricated metals, machinery, and transportation equipment [accessed January 28, 2015]

Ingram AJ, King DJ, Grasso P, Sharratt M. 1993. The early changes in mouse skin following topical application of a range of middle distillate oil products. J Appl Toxicol 13: 247–257.

Institute of Petroleum. 1992. Test Standard IP 346, Determination of polycyclic aromatics in unused lubricating base oils and asphaltene free petroleum fractions - Dimethyl sulphoxide extraction refractive index method. Energy Institute, London, UK.

Jee SH, Wang JD, Sun CC, et al. 1985. Prevalence of probable kerosene dermatoses among ballbearing factory workers. Stand J Work Environ Health. 12(1):61-65.

Jokuty P, Whiticar S, Wang Z, Fingas M, Fieldhouse B, Lambert P, Mullin J. 1999. Properties of crude oils and oil products, Volume 2. Environment Canada, Environmental Technology Centre. Report Series No. EE-165.

Kim M, Guerra P, Theocharides M, Barclay K, Smyth SA and Alaee M. 2013. Polybrominated diphenyl ethers in sewage sludge and treated biosolids: effect factors and mass balance. Water Research 47: 6496-6505.

Klein SA, Jenkins D. 1983. The toxicity of jet fuels to fish-II. The toxicity of JP-8 to flagfish (*Jordanella floridae*) and rainbow trout (*Salmo gairdneri*) and golden shiners (*Notemigonus chysoleucas*). Wat Res 17:1213-1220. [cited in CONCAWE 1995].

Korsak Z, Wisniewska-Knypl J, Swiercz R. 1994. Toxic effects of subchronic exposure to n-butyl alcohol and m-xylene in rats. Int J Occup Med Environ Health. 7(2):155-166.

[LNHPD] Licensed Natural Health Products Database. [Database] [modified 2016 Aug 10] Ottawa (ON): Health Canada. [Accessed 2018 Jan 24].

Lyman WJ, Reehl WF, Rosenblatt DH. 1990. Handbook of chemical property estimation methods: environmental behavior of organic compounds. Washington (DC): American Chemical Society [cited in Environment Canada 2014].

MacLean MM, Doe KG. 1989. The comparative toxicity of crude and refined oils to *Daphnia magna* and Artemia. Dartmouth (NS): Environment Canada, Environmental Protection Directorate. Unpublished. Report EE-111.

Mattie DA, Marit GB, Flemming CD, Cooper JR. 1995. The effects of JP8 jet fuel on male Sprague-Dawley rats after a 90-day exposure by oral gavage. Toxicol Indust Health. 11(4):423-435.

McGrath JA, Fanelli CJ, Di Toro DM, Parkerton TF, Redman AD, Leon Paumen M, Comber M, Eadsforth CV, den Haan K. 2018. Re-evaluation of target lipid model-derived HC5 predictions for hydrocarbons. Environ Toxicol Chem. 37(6):1579-1593.

Meridian. 2009. Meridian MSDS Database for Petroleum Products. [Database]. Meridian Environmental Inc. Calgary, AB. Health Canada Internal Document.

[Mobil] Mobil Oil Corporation. 1988. Light cycle oil developmental toxicity screen in rats. Study No. 50511. Princeton (NJ): Mobil Oil Corporation, Environmental and Health Sciences Laboratory. [cited in API 2003].

[Mobil] Mobil Oil Corporation. 1991. Thirteen week dermal administration of Beaumont Coker Light Gas Oil to rats. Final report of Study No. 61996. Princeton (NJ): Mobil Oil Corporation, Environmental and Health Sciences Laboratory. [cited in API 2003].

MSDS [Material Safety Data Sheet]. 2013. ATOSOL 200, Total Petrochemicals and Refining USA, Inc. [accessed 28 June, 2017]

MSDS [Material Safety Data Sheet]. 2014. ATOSOL 200 AN, Total Petrochemicals and Refining USA, Inc.

MSDS [Material Safety Data Sheet]. 2016. ODC®15 Drilling fluid base oil. Sasol Chemicals USA (LLC). [accessed 28 June 2017]

Muijs B, Jonker M. 2010. A closer look at bioaccumulation of petroleum hydrocarbon mixtures in aquatic worms. Environmental Toxicology and Chemistry, V29, 9, pp 1943 – 1949.

Murray DAJ, Lockhart WL, Webster GRB. 1984. Analysis of the water-soluble fraction of crude oils and petroleum products by gas chromatography. Oil Petrochem Pollut. 2: 39-46. [cited in Jokuty et al. 1999]

Nessel CS, Priston RA, McKee RH, Cruzan G, Riley AJ, Hagermann R, Plutnick RT, Simpson BJ. 1998. A comprehensive evaluation of the mechanism of skin tumorigenesis by straight-run and cracked petroleum middle distillates. Toxicol Sci 44: 22–31.

[NHPID] Natural Health Products Ingredients Database [Database]. [modified 2017 Jan 10]. Ottawa (ON): Health Canada. [Accessed 2018 Jan 24].

[NPRI] National Pollutant Release Inventory. 2020. Overview of Reviewed Facility Reported Data. Gatineau (QC): Environment and Climate Change Canada.

[NTP] National Toxicology Program. 1986. Toxicology and carcinogenesis studies of Marine Diesel Fuel and JP-5 Nay Fuel (CAS No. 8008-20-6) in B6C3F1 mice (Dermal Studies). NTP TR 310. RTP, USA

OECD (Organization for Economic Cooperation and Development). 2000. Guidance document on aquatic toxicity testing of difficult substances and mixtures. OECD Environmental Health and Safety Publications, Series on Testing and Assessment No. 23. OECD, Paris, France. [cited in API 2012]

[OECD] Organisation for Economic Co-operation and Development. 2004. Emission scenario document on lubricants and lubricant additives. ENV/JM/MONO(2004)21. Environment Directorate, Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology. November 26.

[Ontario 1994] Ontario Ministry of the Environment and Climate Change. 2017. Water Management: Policies, Guidelines, Provincial Water Quality Objectives. Toronto, Ontario. [accessed 2017 Aug 16]

[Ottawa] Ottawa Sewage Use Program. 2011. Guide for Discharging Wastewater from Industrial Facilities. Ottawa, Ontario. [accessed 2019 April 11]

[Ottawa] City of Ottawa. 2018. Water purification, quality and delivery. City-owned wells and purification plants. Ottawa, ON. [accessed 2018 March 27]

Payne JF, Fancey LL, Hellou J, King MJ, Fletcher GL. 1995. Aliphatic hydrocarbons in sediments: a chronic toxicity study with winter flounder (*Pleuronectes americanus*) exposed to oil well drill cuttings. Can J Fish Aquat Sci 52:2724-2735.

Payne J, Andres C, Whiteway S, Lee K. 2001. Definition of sediment toxicity zones around oil development sites: dose response relationships for the monitoring surrogates Microtox ® and amphipods, exposed to Hibernia source cuttings containing a synthetic base oil. Can Manuscr Rep Fish Aquat Sci No. 2577. August 2001. Ottawa (ON): Department of Fisheries and Oceans.

[PETROTOX] PETROTOX Estimation Model. 2011. Version 3.06. Conservation of Clean Air and Water in Europe (CONCAWE). Brussels (BE). [accessed 2018 March 16]

PMRA list of formulants. 2010. Pest Management Regulatory Agency. Ottawa (ON): Health Canada, [accessed 2018 March 16].

Potter T, Simmons K. 1998. Composition of petroleum mixtures. Vol 2. Total Petroleum Hydrocarbon Criteria Working Group Series. Amherst (MA): Association for Environmental Health and Sciences Foundation.

Redman AD, Parkerton TF, McGrath JA, Di Toro DM. 2012. PETROTOX: An aquatic toxicity model for petroleum substances. Env. Tox. Chem. 31: 2498-2506.

[RIVM] Consumer Exposure Model (ConsExpo) 2006a. Version 4.1. The National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu). Bilthoven, Netherlands.

[RIVM] The National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu). 2006b. Cleaning Products Fact Sheet. Bilthoven, Netherlands.

[RIVM] The National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu). 2006c. Cosmetics Fact Sheet. Bilthoven, Netherlands.

[RIVM] The National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu). 2007. Do-It-Yourself Products Fact Sheet, Bilthoven, Netherlands.

Rozen MG, Snyder CA, Albert RE. 1984. Depressions in B- and T-lymphocyte mitogen-induced blastogenesis in mice exposed to low concentrations of benzene. Tox Lett. 20:343-349.

Schreiner C, Bui Q, Breglia R, Burnett D, Koschier F, Podhasky P, Lapadula L, White R, Feueston M, Krueger A, Rodriquez S. 1997. Toxicity evaluation of petroleum blending streams: Reproductive and developmental effects of hydrodesulfurized kerosene. J Toxicol Environ Health 52: 211-229.

SDS [Safety Data Sheet]. 2021. Diesel Fuel. Petro-Canada [accessed 6 July 2021]. [SENES] SENES Consultants Limited. 2009. Review of current and proposed regulatory and non-regulatory management tools pertaining to selected petroleum substances under the Chemicals Management Plan. Ottawa (ON): Health Canada.

Shin KH, Jung H, Chang P, Choi H, Kim KW. 2005. Earthworm toxicity during chemical oxidation of diesel-contaminated sand. Environ Toxicol Chem. 24:1924-1929.

Siemiatycki J, Dewar R, Nadon L, Gerin M, Richardson L, Wacholder S. 1987. Associations between several sites of cancer and twelve petroleum-derived liquids. Scan J Work Env Health 13:493-504.

[SimpleTreat] Sewage Treatment Plant Removal Model version 3.1. 2003. Bilthoven (NL): National Institute for Public Health and the Environment (RIVM). Available from: National Institute for Public Health and the Environment (RIVM), Laboratory for Ecological Risk Assessment, Bilthoven, the Netherlands.

Singer MM, Aurand DV, Coelho GM, Bragin GE, Clark JR, Sowby M, Tjeerdema RS. 2001. Making, measuring, and using water-accommodated fractions of petroleum for toxicity testing. International Oil Spill Conference Volume 2. International Oil Spill Conference Proceedings: March 2001, Volume 2001, No. 2: 1269-1274.

Speight, J. 2007. The Chemistry and Technology of Petroleum, 4th ed., CRC Press, Taylor & Francis Group, Boca Raton. [cited in API 2012].

Stacey B, Marcotte B. 1987. Chronic effect of no. 2 fuel oil on population dynamics of harpacticoil copepods in experimental marine mesocosms. Mar Ecol Prog Ser 40: 61-68.

Staikova M, Messih P, Lei YD, Wania F, Donaldson DJ. 2005. Prediction of subcooled vapor pressures of nonpolar organic compounds using a onve-parameter QSPR. J Chem Eng Data. 50:438-443.

Statistics Canada. 2009. Industrial water use. Environment Accounts and Statistics Division, catalogue no. 16-401-X, ISSN 1916-1514, www.statcan.gc.ca/pub/16-401-x/16-401-x2012001-eng.pdf.

Sunito L, Shiu WY, MacKay D. 1986. Analysis of water soluble fractions of crude oils and refined products. Dept. of Chemical Engineering and Applied Chemistry, University of Toronto, Canada. For Environment Canada, C&P, Contract No. 0164. [cited in Jokuty et al. 1999].

Swigert JP, Lee C, Wong DCL, Podhasky P. 2014. Aquatic hazard and biodegradability of light and middle atmospheric distillate petroleum streams. Chemosphere 108: 1-9

Toronto. 2014. Toronto, Ontario. Municipal code Chapter 681, Sewers. March 20. [accessed 2019 April 11]

[UN] United Nations. 2011. Globally Harmonized System of Classification and Labelling of Chemicals (GHS). Geneva, Switzerland. ST/SG/AC.10/Rev.4 [accessed 2017, August]

[US EPA 1993] US Environmental Protection Agency. 1993. Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons; Office of Research and Development: Washington, DC, USA.

[US EPA] US Environmental Protection Agency. 2008. Transportation and marketing of petroleum liquids. In: AP 42. 5th ed. Vol. 1. Washington (DC): US EPA. Chapter 5, Petroleum industry; section 5.2; p. 5.2-1 to 5.2-17. [accessed 2020, May]http://www.epa.gov/ttn/chief/ap42/ch05/final/c05s02.pdf

[US EPA 2011] US Environmental Protection Agency. 2011a. Exposure Factors Handbook 2011 Edition. Office of Research and Development: Washington, DC, USA.

[US EPA] US Environmental Protection Agency. 2011b. Screening level hazard characterization. Kerosene/Jet Fuel Category. Office of Pollution Prevention and Toxics (OPPT): Washington, DC, USA.

[US EPA] United States Environmental Protection Agency. 2013. Priority Pollutants. Webpage. [accessed 2015 May 15]

Vargo G, Hutchins M, Almquist G. 1982. The effect of low, chronic levels of no. 2 fuel oil on natural phytoplankton assemblages in microcosms: 1. Species composition and seasonal succession. Mar Environ Res 6: 245-264.

Walborg EF, DiGiovanni J, Conti CJ, Slaga TJ, Freeman JJ, Steup DR, Skisak CM. 1998. Short-term biomarkers of tumor promotion in mouse skin treated with petroleum middle distillates. Toxicol Sci 45:137–145.

Wahlberg JE. 1995. ‘Green diesel’ – skin irritant properties of diesel oils compared to common solvents. Contact Dermatitis 33:359-360.

Wang, X,,Bartha R. 1990.. Effects of bioremediation on residues, activity and toxicity in soil contaminated by fuel spills. Soil Biol. Biochem. 22::501-505. [Cited in CONCAWE 1996a]

Warner ML, Sauer RH, Carlile DW. 1984. Barley growth in coal liquid and diesel liquid fuels from coal and oil: a comparison of potential toxic effects on barley. Water Air Soil Pollut. 22:47-55.Westat, Inc. 1987. National Usage Survey of Household Cleaning Products. Prepared for U.S. EPA, Office of Toxic Substances. EPA Contract No. 68-02-42431987.

Westat. 1987. Household solvent products: A national usage survey. Washington, DC. US Environmental Protection Agency.

White Jr KL, DeLorme MP, Beatty PW, Smith MJ, Peachee VL. 2013. Jet Fuel Kerosene is not immunosuppressive in mice or rats following inhalation for 28 days. J Toxicol Environ Health, Part A, 76:13, 778-797.

Williams JH. 1999. Regulations on additions of sludge-borne metals to soil and their adaptation to local conditions. In L’Hermite P (editor)’s Treatment and use of sewage sludge and liquid agricultural wastes, 243-250. London (GB): Commission of the European Communities.

Appendices

Appendix A. Twenty-six Industry-restricted Gas Oils and Kerosenes

Table A-1. Chemical Abstracts Service Registry Number (CAS RN) and Domestic Substance List (DSL) of 26 Industry-restricted Gas Oils and Kerosenes

CAS RN	DSL Name
64741-43-1	Gas oils (petroleum), straight-run
64741-49-7	Condensates (petroleum), vacuum tower
64741-58-8	Gas oils (petroleum), light vacuum
64741-60-2	Distillates (petroleum), intermediate catalytic cracked
64741-90-8	Gas oils (petroleum), solvent-refined
64742-06-9	Extracts (petroleum), middle distillate solvent
64742-30-9	Distillates (petroleum), chemically neutralized middle
64742-31-0	Distillates (petroleum), chemically neutralized light
64742-72-9	Distillates (petroleum),catalytic dewaxed middle
64742-77-4	Distillates (petroleum), complex dewaxed middle
64742-87-6	Gas oils (petroleum), hydrodesulfurized light vacuum
64742-91-2	Distillates (petroleum), steam-cracked
68333-88-0	Aromatic hydrocarbons, C9-17
68477-30-5	Distillates (petroleum), catalytic reformer fractionator residue, intermediate-boiling
68814-87-9	Distillates (petroleum), full-range straight-run middle
68915-96-8	Distillates (petroleum), heavy straight-run
68915-97-9	Gas Oils (petroleum) straight-run, high-boiling
68919-17-5	Hydrocarbons, C12-20, catalytic alkylation by-products
68921-07-3[a]	Distillates (petroleum), hydrotreated light catalytic cracked
92704-36-4	Gas oils (petroleum), straight-run, clay-treated
128683-26-1	Distillates (petroleum), full-range atm.
128683-27-2	Distillates (oil sand), straight-run middle
128683-28-3	Gas oils (petroleum), full-range
128683-29-4	Gas oils (oil sand), hydrotreated
128683-30-7	Gas oils (oil sand)
129893-10-3	Residues (petroleum), vacuum, hydrocracked, middle distillate fraction

[a] This substance was not identified under subsection 73(1) of CEPA but was included in this assessment as it was considered a priority through other mechanisms.

Appendix B. Factors used to Determine Human Health Effects from Environmental Media Exposures

Table B-1. Variable inputs to SCREEN3 calculation of industrial exposure of the general population to gas oil and kerosene substances

Variables	Input Value
Source type[a]	Area
Effective emission area[a]	100 m × 120 m
Emission rate (g/s•m^2)[b]	4.2×10^{-4}
Source release height (m)[a]	8
Receptor height (m)[c]	1.74
Variable wind adjustment factor	0.4 (daily average) , 0.2 (yearly average)
Urban/Rural option[a]	Urban
Type of meteorology[d]	Full
Minimum and maximum distance (m)	10 – 1 000

[a] Professional judgement based on aerial photo analysis
[b] Estimated based on the highest quantity of the substance released during the 2017 reporting year by a single submitter and an assumed continuous release (NPRI 2022).
[c] Curry et al. (1993)
[d] Regulatory default from the SCREEN3 model

Appendix C. Industry-restricted Gas Oil and Kerosene substances on ECHA (2012) list

Table C-1. Industry restricted gas oil and kerosene substances in ECHA carcinogenic, mutagenic, or reproductive toxin (CMR) list. (ECHA 2012)

CAS RN	CMR	Common name
64741-43-1	No	NA
64741-49-7	No	Vacuum tower condensate
64741-58-8	No	Light vacuum gas oils
64741-60-2	Yes - Carc. 1B	Cracked gasoil
64741-90-8	Yes	Solvent-refined gas oils
64742-06-9	No	Middle distillate solvent extract (petroleum)
64742-30-9	Yes - Carc. 1B	NA
64742-31-0	No	Chemically neutralized light distillate (petroleum), Kerosene - unspecified
64742-72-9	No	NA
64742-77-4	No	Complex dewaxed middle distillate (petroleum)
64742-87-6	No	Hydrodesulfurized light vacuum gas oil (petroleum)
64742-91-2	No	Cracked kerosene
68333-88-0	No	NA
68477-30-5	Yes - Carc. 1B	Gasoil – unspecified, light aromatic (petroleum)
68814-87-9	No	Full range straight run middle distillate (Petroleum)
68915-96-8	No	NA
68915-97-9	No	NA
68919-17-5	No	Heavy alkylate hydrocarbons
68921-07-3	No	Light catalytic cracked petroleum distillate, hydrotreated
92704-36-4	No	NA
128683-26-1	No	NA
128683-27-2	No	NA
128683-28-3	No	NA
128683-29-4	No	NA
128683-30-7	No	NA
129893-10-3	No	NA

Abbreviations: CMR – carcinogenic, mutagenic, or reproductive toxin; NA – Not available.