Petroleum Substances Review: Lubricating Oils

Non-Confidential Summary

Prepared for

Environment Canada

Report by

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Notes For Reader

The following draft report has been prepared for Environment Canada.

The opinions, findings, conclusions, and recommendations expressed within this report are those of the consultant and do not bind the Government of Canada or any of its ministries or departments to act on or commit to any of the conclusions and recommendations.

This report contains a series of numerical estimates that were used to segment the lubricating oil market in Canada. Except where noted, these estimates were the result of informed judgements by the author based on experience in the lubricants industry, discussions with industry colleagues, and amalgamations of various pieces of published data that each contained portions of market data describing the lubricating oil industry in Canada.

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1.0 Introduction

1.1 Background

Environment Canada has requested a review of the disposition of lubricating oils from the point of production at the oil refinery to their commercial applications and consumption. This review will provide key information towards the Government of Canada's Chemical Management Plan to regulate chemicals that are harmful to human health or the environment.

Lubricating oils identified by Chemical Abstract Service Registry Numbers (CAS RN's) are listed as high and medium priority substances on the Domestic Substances List (DSL) which is a listing of all chemical substances that enter commercial trade in Canada. The information requested for this study includes the use, environmental release points, and potential routes for human exposure of lubricating oils. The scope of the consumption information will cover all sectors in Canada, except the petroleum refining sector for which the government has different information needs that are covered under other information gathering exercises. However, the role of the Canadian petroleum sector in lubricating oil supply is outlined to ensure understanding of the total value-chain.

1.2 Methodology

This report includes a detailed supply chain analysis describing the distribution and consumption of lubricating oils, identification and discussion of the releases of substances derived from lubricating oils to the environment, as well as identification of points during distribution and consumption where there is the potential for human exposure. The following steps describe the methodology used to complete this project.

1. An overview and analysis of the Canadian lubricant and process oil markets was completed. This formed the basis for analysing the relative use of each lubricating oil type.
2. High and medium priority petroleum substance CAS RN's and their descriptions were reviewed in order to identify those that refer to lubricating oils.
3. All North American lubricating oil refinery web pages were reviewed to determine CAS RN's associated with lubricating oils currently entering commerce.
4. Each of the substances that enter commerce was categorized into three groups according to the American Petroleum Industry base oil classification system.
5. Estimated volumes of each of the three types of oil were allocated to the various segments of the automotive, industrial and process oil markets.
6. An assessment of lubricating oil supply and distribution was completed.
7. The supply and distribution schemes were used to assign points of potential releases of lubricating oils to the environment as well as modes of potential human contact.

2.0 Discussion

2.1 Overview of Lubricating Oils

Lubricating oil is a general term that refers to liquid fractions produced at crude oil refineries that are heavier than liquid fuels and of a viscosity that is desired for providing lubricating performance for machinery and equipment. The majority of lubricating oils are directed towards lubricants production, which is known as the base oil market. The remaining portion is consumed in non-lubricant applications, such as chemicals or solvents. These applications are referred to as the process oil market. Base oils and process oils are essentially identical, but may be produced to slightly different specifications and sold under different brand names into the two different markets.

A variety of lubricating oil grades are produced from crude oil by both conventional and advanced refining methods. Conventional refining begins with fractionation via vacuum distillation, which produces gases, liquid fuels, heavier liquids that serve as lubricating oils, and heavier fractions for asphalt or solid fuel. The liquid product is often referred to as petroleum distillate or vacuum gas oil. A second stage process for lubricating oil production involves solvent extraction, which removes aromatics and other impurities, such as sulphur and nitrogen containing organic materials, to produce what is known as raffinate. Next, waxy fractions are removed in the dewaxing stage to provide improved low temperature properties. Hydrofinishing is the final stage of the process and is a relatively mild hydrogenation step that increases the level of saturation of the oil and improves the oxidation stability of the oil.

In order to produce higher purity base oils, a range of advanced hydroprocessing, catalytic isomerisation, and catalytic dewaxing technologies are used.

2.2 Lubricant Base Oil Classification

The primary sector that has implemented industry wide standards, practices, and quality levels for lubricants is the automotive lubricants industry. The Engine Oil Licensing and Certification System (EOLCS) has been developed through a collaborative effort by the lubricants industry. It is published by the American Petroleum Institute (API) and includes lubricant performance standards as well as base oil standards.

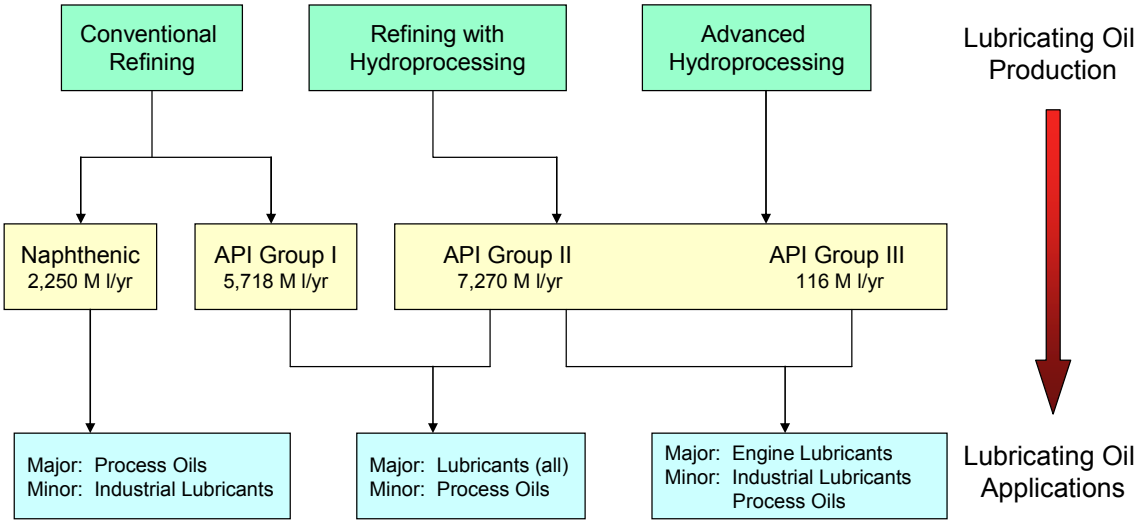
The API 1509 base oil classification system is shown in Table 1. API 1509 is widely accepted around the world and categorizes lubricating oils according to basic chemical composition and viscosity characteristics.

Table 1. API Publication 1509 – Base Oil Classifications[1]

	Viscosity Index[2]	Saturates		Sulphur	Description
Group I	80 - 120	<90%	and/or	≥0.3%	
Group II	80 - 120	≥90%	and	<0.3%	
Group III	>120	≥90%	and	<0.3%	
Group IV					poly alphaolefins (synthetic)
Group V					all others – naphthenics aromatic oils, esters, phosphates, polyglycols, silicones

Approximately 95% of lubricants in North America (as well as Canada) are based on refined oils, which are in the Group I, II, and III categories.[3] An overview of the production and use of lubricating oils in North America is summarized in Figure 1. The base oil production is based on lubricating oil refining capacity as published by Lubes 'N' Greases and the main applications reflect general trends of the lubricants industry.

Figure 1. North America Lubricating Oil Production[4]



[1] API 1509 Engine Oil Licensing and Certification System, Appendix E. http://www.api.org/certifications/engineoil/pubs/index.cfm
[2] Viscosity Index is a standard measurement of an oil's viscosity change relative to temperature.
[3] www.npra.org
[4] 2008 Lubes 'N' Greases Guide to Global Base Oil Refining

A review of the high priority substances from the Domestic Substance List along with on-line research into the lubricating oils offered by each North American refinery were used to identify lubricating oil CAS RN's that currently enter, or have the potential to enter commerce in Canada. Each substance was grouped into API 1509 base oil classifications based on its properties and/or description.

- Group I base oils are typically solvent refined or solvent dewaxed and are described as heavy paraffinic or heavy naphthenic neutral distillates.
- Group II and Group III base oils are typically hydrotreated, thermal cracked or catalytic cracked based on the more extensive hydroprocessing required to produce them.
- Conventionally refined lubricating oils that have less than 60% paraffinic content are referred to as naphthenic oils, which fall under the Group V category.

It is not feasible to trace the path of use for each individual substance due to the complex nature of the lubricating oil market. Multiple CAS RN's may be used to describe similar substances, commercial oils may include blends of CAS RN's, and most lubricating oils have the potential for use in multiple applications. However, since there are trends in how the different types of lubricating oils are used, the high and medium priority substances were grouped by the API classifications. The conclusion of the investigation and categorization of lubricating oil CAS RN's is provided as Table 2. That is, Table 2 provides the list and categorizations of lubricating oil CAS RN's that are commercially available and may enter commerce in Canada.

Table 2. Potentially Commercial High & Medium Priority Lubricating Oils*

API Group I	API Group II/III	Naphthenic
64741-45-3	64742-54-7	64741-96-4
64741-88-4	64742-55-8	64742-52-5
64741-89-5	64742-58-1	64742-53-6
64741-95-3	72623-83-7	
64742-01-4	72623-84-8	
64742-04-7	72623-85-9	
64742-46-7	72623-86-0	
64742-47-8	72623-87-1	
64742-62-7	178603-64-0	
64742-65-0	178603-65-1	
	178603-66-2	
	445411-73-4	

* Lubricating oils listed on the DSL that are manufactured and commercially available in North America and have the potential to enter commerce in Canada.

2.3 Lubricating Oil Applications

The uses of lubricating oils can be categorized broadly in two types of applications. Approximately 85% is used as base oil for lubricant formulations with the remaining 15% consumed as process oils.[5] In addition, the industry commonly segments lubricants into automotive and industrial applications.

2.3.1 Process Oil Applications

Process oils are lubricating oils that are used in non-lubricating applications where the oils are used as a chemical or solvent. Process oils contain little or no additives and the oils are consumed as part of the manufacture and production of other products.

- Electrical Insulating and Transformer Oils - the largest application is for use in oil cooled transformers as well as other oil filled electrical equipment such as circuit breakers, switches, and cables.
- Rubber Extending - are oils used as part of rubber formulations in order to produce the required flexibility or softness characteristics of the rubber.
- White Oils – are ultra purified oils that are clear, colourless, tasteless, and odourless manufactured to FDA, US Pharmacopeia (USP), and US Formulary specifications for use in pharmaceuticals, personal care products, and food processing. Technical grade white oils are often used to manufacture food grade lubricants, elastomers and plasticizers for polymer manufacture, ink oils, and grain dust suppressants.[6]
- Agricultural Spray Oils - are used as pesticides mainly for fruit trees, although the mode of action is not biological, rather, the oil acts by suffocating the pests.
- Other Process Oils - oil used as low volatility solvents in ink formulations, flow improvers in melted polymer during polymer manufacture, leather tanning and preservation products, and additives for paints, coatings, adhesives, and sealants.[7]

2.3.2 Lubricant Applications

The lubricants market is segmented into two main sectors – automotive and industrial. Automotive oils are targeted for use in mobile equipment, where as industrial oils are typically used in manufacturing plants.

Automotive oils include:
- motor oils for gasoline powered cars,
- heavy duty diesel oil for diesel powered on-road and off-road trucks, buses and heavy duty equipment,

[5] *Lubricating Oils and Wax Sales*, www.npra.org
[6] http://www.sonneborn.com/products/usp_nf_white_mineral_oils.htm
[7] http://www.calumetspecialty.com/applications-calsol.html

- automatic transmission fluids (Dexron®, Mercon®) for light duty cars and trucks, universal tractor fluids commonly used in farm tractors and other off-highway mobile equipment, and hydraulic oils used in power steering pumps and shock absorbers,
- heavy duty gear oils (80W-90) used in trucks and off-highway equipment.

Lubricants included in the industrial oil category are:

- hydraulic oils used in manufacturing plants and in supplementary equipment mounted on trucks, construction, and forestry equipment
- turbine, bearing and circulating oils, used in steam turbine bearings, and in steel manufacturing equipment.
- industrial gear oils
- lubricants used in range of manufacturing plant equipment, such as compressors, refrigeration units, rock drills/air tool, and greases.
- natural gas engine oils (natural gas compression and transmission)
- marine engine oils (which use very low quality fuel)
- railroad engine oils
- metalworking fluids used for rolling sheet metal, treating casted metal parts, and lubricating metal drilling, cutting, and grinding operations.

2.4 Lubricating Oil Production and Consumption

There are four lubricating oil production plants (refineries) in Canada, indicated in Table 3, with a total production capacity of 1.46 billion litres paraffinic lubricating oil annually. There is no naphthenic oil production in Canada.

Table 3. Canada Lubricating Oil Production Capacity, M litres[8]

Company	Group I	Group II	Group III	Total
Imperial Oil, Edmonton	119	-	-	119
Imperial Oil, Sarnia	151	205	-	356
Petro-Canada, Mississauga	-	735	108	843
Shell, Montreal	146			146
Totals	**416**	**940**	**108**	**1,464**

Actual lubricating oil and lubricant production in 2006 was reported by Statistics Canada as 1.29 billion litres, with consumption of 1.13 billion litres.[9] The lubricating oil market has remained generally flat in North America for nearly 10 years,[10] and therefore, using 2006 as a typical year, the net annual supply and consumption of lubricating oils in Canada is shown in Table 4.

[8] 2008 Lubes 'N' Greases Guide to Global Base Oil Refining
[9] Statistics Canada Catalogue #57-003-X (2006) Table 5-1. http://www.statcan.gc.ca/pub/57-003-x/57-003-x2006000-eng.pdf
[10] www.npra.org

Table 4. Annual Canadian Lubricating Oil Supply and Consumption, M litres

Production	Exports	Imports	Adjustment for Additives[11]	Lubricant Consumption	Process Oil Consumption
1,289	(614)	406	49	1,010	120

The values presented in Table 4 were derived as follows:

- The total base oil available was reported by Statistics Canada to be 1.03 billion litres.
- Total lubricant consumption reported by Statistics Canada was 1.13 billion litres.
- Of the 406 litres of imported lubricating oils reported, an estimated 356 million litres is assigned as being formulated product, with 50 million litres imported as base oil. This is based on a general assumption that US lubricant manufacturing costs are lower and therefore it more costly to import base oil and additive for blending in Canada.
- Of the 614 million litres reported as exports, the volume of base oil is arbitrarily set at 65% or 404 million litres, with 210 designated as formulated products. This estimate is based on the assumption that for US importers, it would generally be more cost effective to import base oil from Canada for blending and packaging in the US, rather than importing fully formulated product.
- Most exports are considered to be base oil based on Petro-Canada's high production of premium Group II and Group III oils, and its leading position of white oil production.[12]
- Following the exports of 614 million litres, the net volume of lubricating oil available for lubricant and process oil production is 725 million litres.
- Of the 725 million litres of lubricating oil, 120 million litres are consumed as is, as process oils[13], leaving 605 million litres available for lubricant manufacture.
- Using an average addition rate of 8% additives[14] in lubricant formulations, the total volume of lubricants manufactured in Canada is 654 million litres (605 x 1.08).
- This results in total lubricant consumption of 1.01 billion litres (654 + 356 imported).

The applications of lubricating oils can also be segmented by oil type, and this is shown in Table 5. Specific data for the use of each base oil category is not available, but estimates can be made using known industry trends for oil use and aligning these trends with known application volumes.[15]

Naphthenic oils are use in applications where certain solubility and low temperature properties are required, since these are two areas where the cycloparaffinic nature of naphthenic oils provides advantages over paraffinic stocks. These include transmission fluids, metal working fluids, and refrigeration oils, as well as many of the process oil

[11] Total lubricant consumption accounts for lubricating oil plus an average of 8% chemical additives
[12] http://lubricants.petro-canada.ca/en/news/2404.aspx?id=2451
[13] Estimated from combined data sources: Statistics Canada, Freedonia, BCUOMA, and NPRA reports
[14] Lubricants require performance additives at treat rates that vary between 3 – 15% depending on the application. 8% was used as an average.
[15] Lubricant use in Canada was published by BCUOMA, http://www.usedoilrecycling.com/resources/file/BC/BCConsumedstudy.pdf

applications. Naphthenic oils are not used in automotive engine oils due to their low viscosity indices. On the process oil side, naphthenic oils are commonly used as electrical insulating oils based on their electrical insulating properties.

Group I oils are widely used in almost every lubricant application as the lowest cost base stock.

Group II/III oils can also be used in virtually all lubricating oil applications. However, these base oils are more often used in lubricants in order to produce higher quality products. For example, a high proportion is used in automotive applications in order to meet the latest specifications of engine oils (such as 5W-30, 5W-40 and 5W-20 grades) as well as automatic transmission oils. Group II/III oils are widely used in white oil and other process oil applications, particularly where clear and colourless oils are required.

Table 5. Lubricating Oil Consumption by Oil Type, M litres[16]

Oil Type	Automotive Lubricants	Industrial Lubricants	Process Oils	Total
Naphthenic	5	11	25	41
Group I	445	223	17	685
Group II/III	274	52	78	404
Total	**724**	**286**	**120**	**1,130**

2.5 Disposition of Lubricating Oils

A detailed review of the end of use disposition of lubricants and process oils was conducted and the results are summarized in Tables 6 and 7.

Lubricants used in Canada have received considerable attention from government and industry to ensure appropriate handling, use, and disposal. The National Used Oil Material Advisory Council (NUOMAC)[17] was formed as a joint council of industry led provincial used oil management associations from British Columbia, Alberta, Saskatchewan, Manitoba, and Quebec. Other provinces have their own waste management systems to deal with used oil.

Key resources for used lubricant disposition were estimates of used lubricant consumption, recycling, and disposal rates reported in two studies conducted in 2005 and 2006 by the British Columbia Used Oil Management Association (BCUOMA).[18,19]

[16] Estimates based on discussions with industry experts
[17] http://www.usedoilrecycling.com
[18] http://www.usedoilrecycling.com/resources/file/BC/BCConsumedstudy.pdf

Three primary end of use pathways are identified for used lubricants.

- A large portion of oils are collected and either rerefined or otherwise reused in such ways as being burned for heating value, consumed in explosives manufacture, or disposed through land filling of waste materials that contain used oil residue
- Lubricants are consumed during normal equipment operation such as losses via combustion in internal combustion engines and volatility losses in high temperature applications,
- Uncontained losses of oil occur during use by way of leaks, spills, and oil usages that are not or cannot be recovered or contained (such as open gear greases and chain lubricants).

NUOMAC maintains records of used oil collection and, while there are regional variations, approximately 52% of all lubricants sold are collected after use for recycling in Canada. The BCUOMA studies[18,19] also estimated that an overall average of 30% of lubricants are lost during use and is therefore unavailable for collection. This is the Consumed in Used and Uncontained Dispersions volume shown in Table 6 (a value of 28.7% was determined for this study). The reports also estimated that 20% of lubricants are in someway utilized or disposed of such that this volume is also unaccounted for by the used oil collection system. This volume is represented by the Onsite Burning, Land Filled, and Explosives Manufacture.

Virtually all process oils are consumed in their applications. The modes of consumption are as chemical components of manufactured products, where the mineral oil is “fixed” in its application, as well as use as components in blended products such as personal care and coatings. Two exceptions are agricultural spray oil, where the oil is purposely dispersed as part of crop treatments, and transformer oils that may be recovered and recycled as transformers are replaced.[20] A summary of the disposition of process oils is provided in Table 7.

[19] http://www.usedoilrecycling.com/resources/file/BC/Unaccountedstudy.pdf
[20] http://www.hydrodec.com/hydrodec_introduction.php

Table 6. End of Use Disposition of Lubricants

		Volume, M Litres	% of Total
Recycled, Reused, Disposed	**Collected and Recycled**	525	52.0%
	On Site Burning	162	16.0%
	Land filled	20	2.0%
	Explosives Manufacture	13	1.3%
	Subtotal	**720**	**71.3%**
Consumed in Use	**Consumed in Use**	**154**	**15.2%**
Uncontained Dispersions	**Spill/Leaks**	53	5.2%
	Improper Disposal	32	3.2%
	Reused / Consumed	20	2.0%
	Total Loss Applications	31	3.1%
	Subtotal	**136**	**13.5%**
Total		**1,010**	

Table 7. End of Use Disposition of Process Oils

		Volume, M Litres	% of Total
Recycled, Reused, Disposed	**Collected and Recycled**	19	16.0%
	On Site Burning		
	Land filled	5	4.0%
	Explosives Manufacture		
	Subtotal	**24**	**20.0%**
Consumed in Use	**Consumed in Use**	**80**	**71.0%**
Uncontained Dispersions	**Spill/Leaks**		
	Improper Disposal		
	Reused / Consumed		
	Total Loss Applications	16	9.0%
	Subtotal	**16**	**9.0%**
Total		**120**	

- Process oils that are consumed in rubber products (mostly tires) and plastics are classified as "Consumed in Use" applications. The subsequent disposition of these products was not included as part of this present study. In addition, it is assumed that the oils consumed in rubber and plastic manufacture have been in some way chemically transformed.

- White oils are used in a range of applications including additives for plastics (polystyrene), pharmaceutical and personal care products, and food additives.[21] Therefore, white oil consumption was largely considered as total loss applications. It should be noted that white oils used in some personal care products will ultimately end up in municipal sewage systems as a result of normal human use.

- Electrical oil used to fill transformers commonly remain in place for 20 years or more. When transformers are replaced, the oil can be recycled or incinerated. It is likely that most transformer oil is collected and recycled. Electrical oils used as cable filling oils will ultimately be land filled or incinerated, during the normal industry practices for disposal of used electrical cables and equipment.

- Agricultural spray oils are normally of white oil quality, and are 100% dispersed as part of crop treatments.

- Other process oil applications, such as ink or coating applications were mostly considered as "consumed in use" as oils used in these applications will ultimately be land filled, incinerated, or otherwise lost during normal industry practices for disposal of the materials to which the inks and coatings were applied.

[21] http://www.icis.com/Articles/2000/02/14/105649/white-mineral-oil-market-in-na-continues-to-strengthen-and.html

2.6 Lubricating Oil Supply and Distribution

Lubricating oils enter commercial trade in three ways. Refining companies can:

1. consume their own base oil production for the manufacturing of formulated products and lubricants that are subsequently marketed and sold,
2. sell lubricating oil, as is, into process oil applications,
3. sell base oil, as is, to other lubricant marketing companies for manufacturing and sale of their brand of lubricants or process oils.

In terms of oil transportation, lubricant suppliers integrated in base oil production will send base oil to adjacent blending and packaging facilities via pipeline and larger imported shipments or shipments to larger 3rd party lubricant blending plants and most product is shipped by rail.

For downstream lubricant supply, the domestic integrated oil companies (Imperial Oil, Shell, and Petro-Canada) supply most of the large lubricant accounts (mines, manufacturing plants, paper mills) directly from the lubricant manufacturing plants, and therefore a portion of this volume will be supplied by rail. Product shipped from blending and packaging plants, as well as other distributor facilities will be moved via a mixture of bulk on-highway tankers, and general freight. Independent lubricant manufacturers tend to operate regionally, with smaller sized customers, and therefore all of their volume (as shown leaving 3rd party blending plants) is expected to ship by truck.

The supply and distribution of lubricants and process oils are provided in Figures 3 -5 which indicate the volumes of each type of lubricating oil that move through the various channels of the supply chain. All volumes are in millions of litres. The CAS RN's associated with each base oil category of lubricating oils are according to the commercialized CAS RN's as indicated in Table 2.

- Figure 2. Supply Chain: Naphthenic Oil - A comparatively larger portion of naphthenic oil is transported by rail. This accounts for the high proportion of naphthenic oil used in process oils for single locations of large manufacturing facilities, such as rubber plants and power companies.

- Figure 3. Supply Chain: API Group I Oil – API Group I oils are used in virtually all applications, which implies both large and small customers. Therefore, a large share of product moves through independent manufacturers and distributors, which implies a larger share of truck transport.

- Figure 4. Supply Chain: API Group II/III Oil – Based on the published production capacity of Group II/III oils by Petro-Canada, a significant proportion of product is estimated to leave the production site via rail for exports. In addition a higher proportion of oil flows through 3rd party blending plants.

Figure 2. Supply Chain: Naphthenic Oil

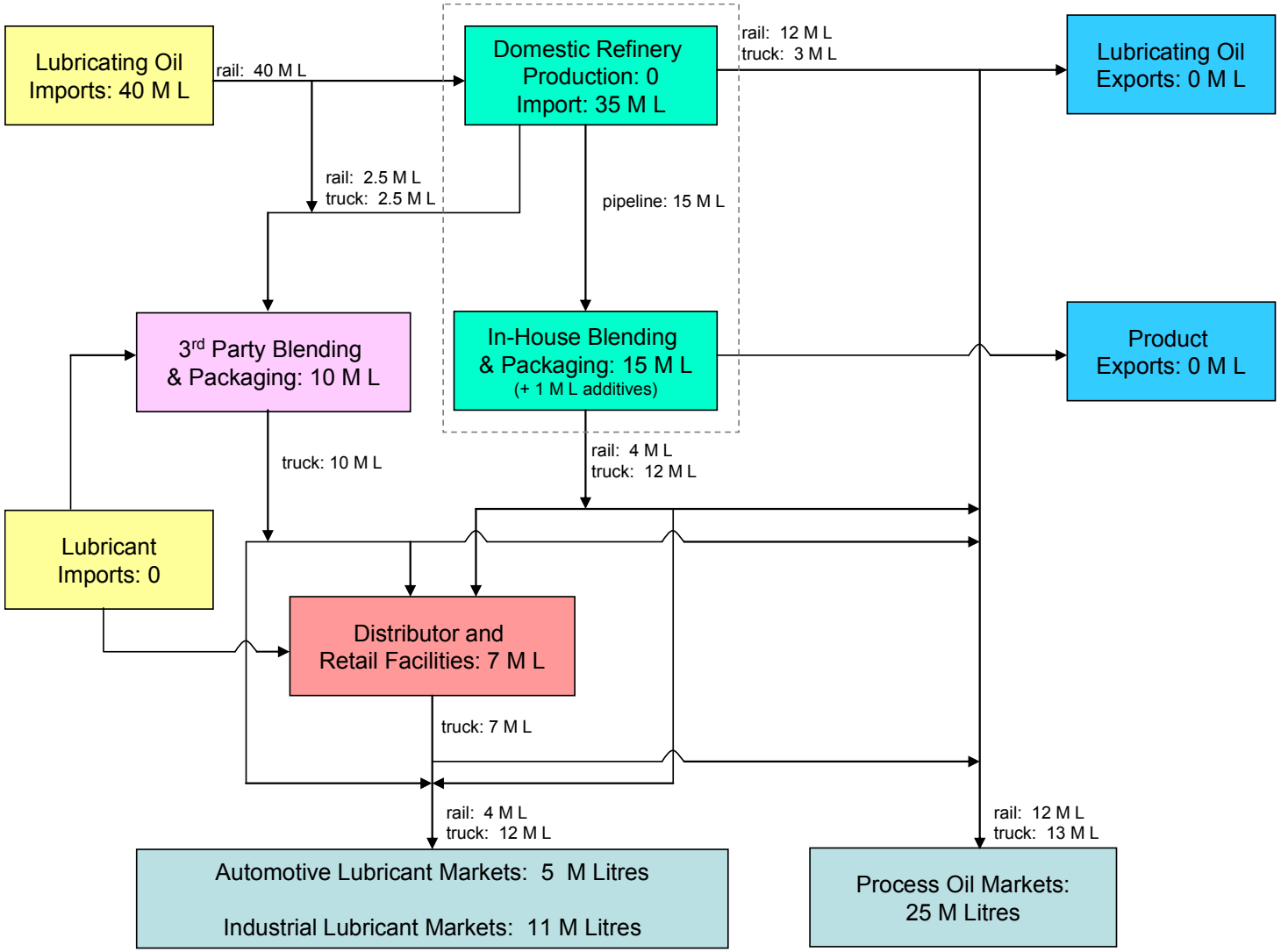


Figure 3. Supply Chain: API Group I Oils

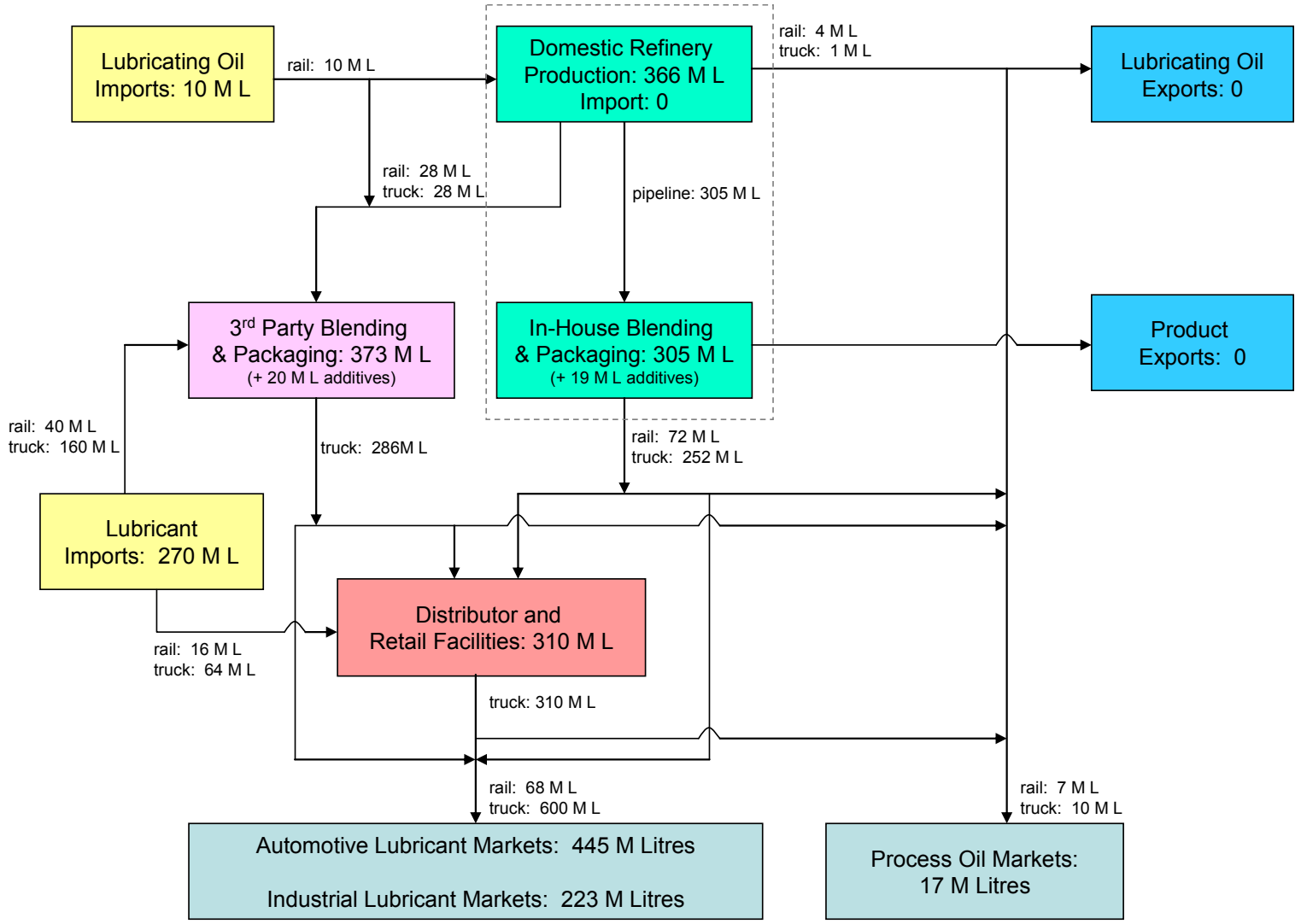
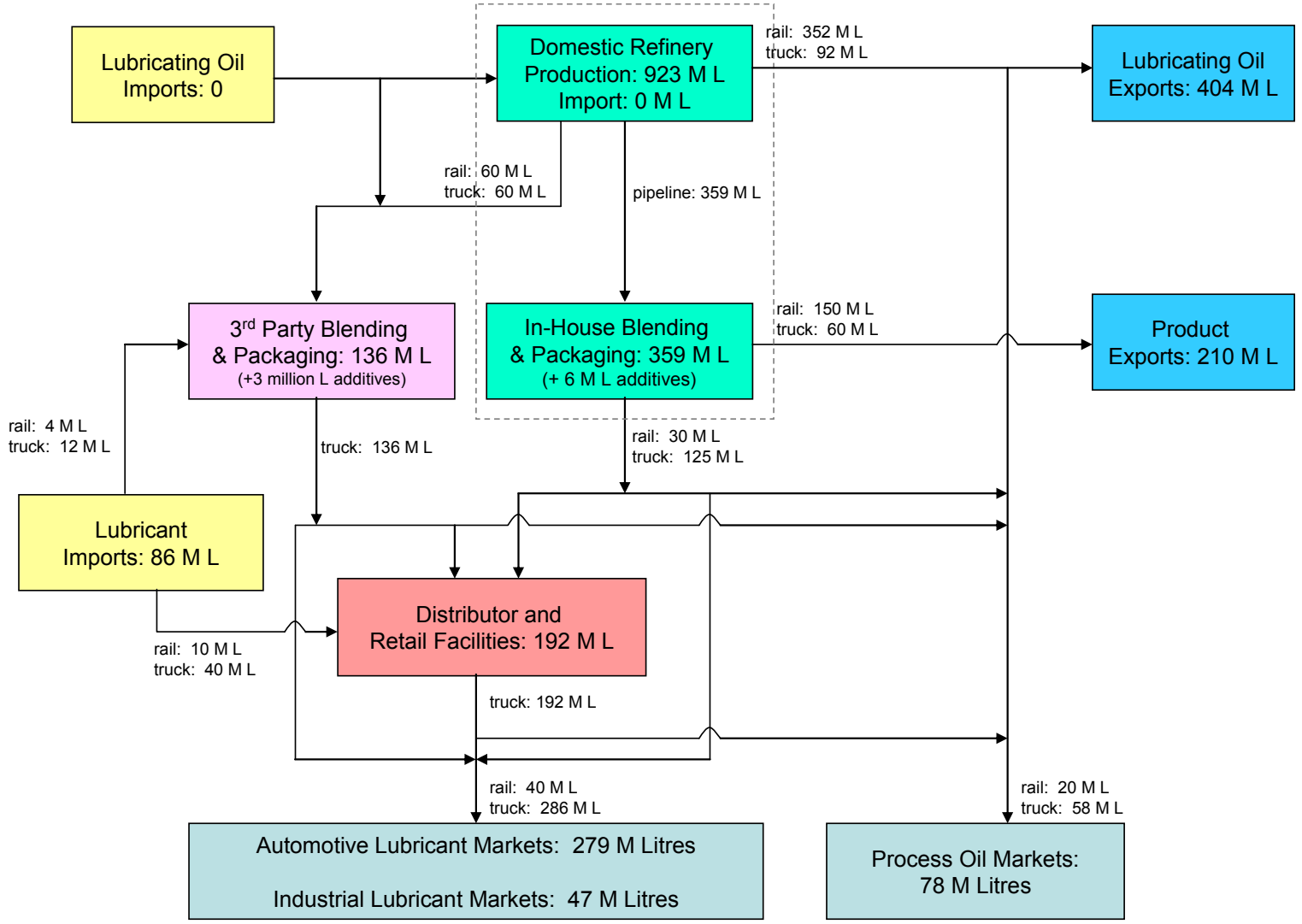


Figure 4. Supply Chain: API Group II/III Oils



2.7 Environmental Releases

2.7.1 Supply and Distribution

Throughout the supply, distribution, and consumption of lubricants and process oils, there is potential for releases to the environment. The elements of the environment that are impacted by lubricating oil releases are designated as land, water, and air.

The potential release points through the supply chain of lubricants and process oils, for each type of lubricating oil, are provided as Figures 5 – 7. While the potential release points are identical for each lubricating oil type, each diagram also indicates the volume of each oil type, which provides an indication of the levels of potential of release.

Key comments regarding the assessment of potential releases to the environment are as follows:

- The potential release to water and land is indicated throughout the transportation side of the supply chain. This potential release is meant to address potential losses due to equipment damage and highway or railway accidents.
- Releases of lubricating oils to land are indicated within the facilities (manufacturing and distribution). While these facilities are required to have spill containment systems, small scale leaks are likely to be cleaned by use of absorbent materials which would be sent to landfill.
- The potential environmental release to the air is considered as nil, as indicated through the supply and distribution system, since lubricants are non-volatile substances.

It is important to note that the probable releases of lubricants to the environment during supply and distribution are minimal compared to the volume of lubricants lost during use. Table 6 shows that a total of 156 million litres of used lubricants are likely to be exposed to the environment during use per year, through uncontained dispersions (136 million litres) plus a quantity disposed in landfills (20 million litres). A detailed analysis of potential environmental exposure to lubricating oils by oil type is shown in Tables 8 – 10.

Figure 5. Naphthenic Oils: Potential Release Points

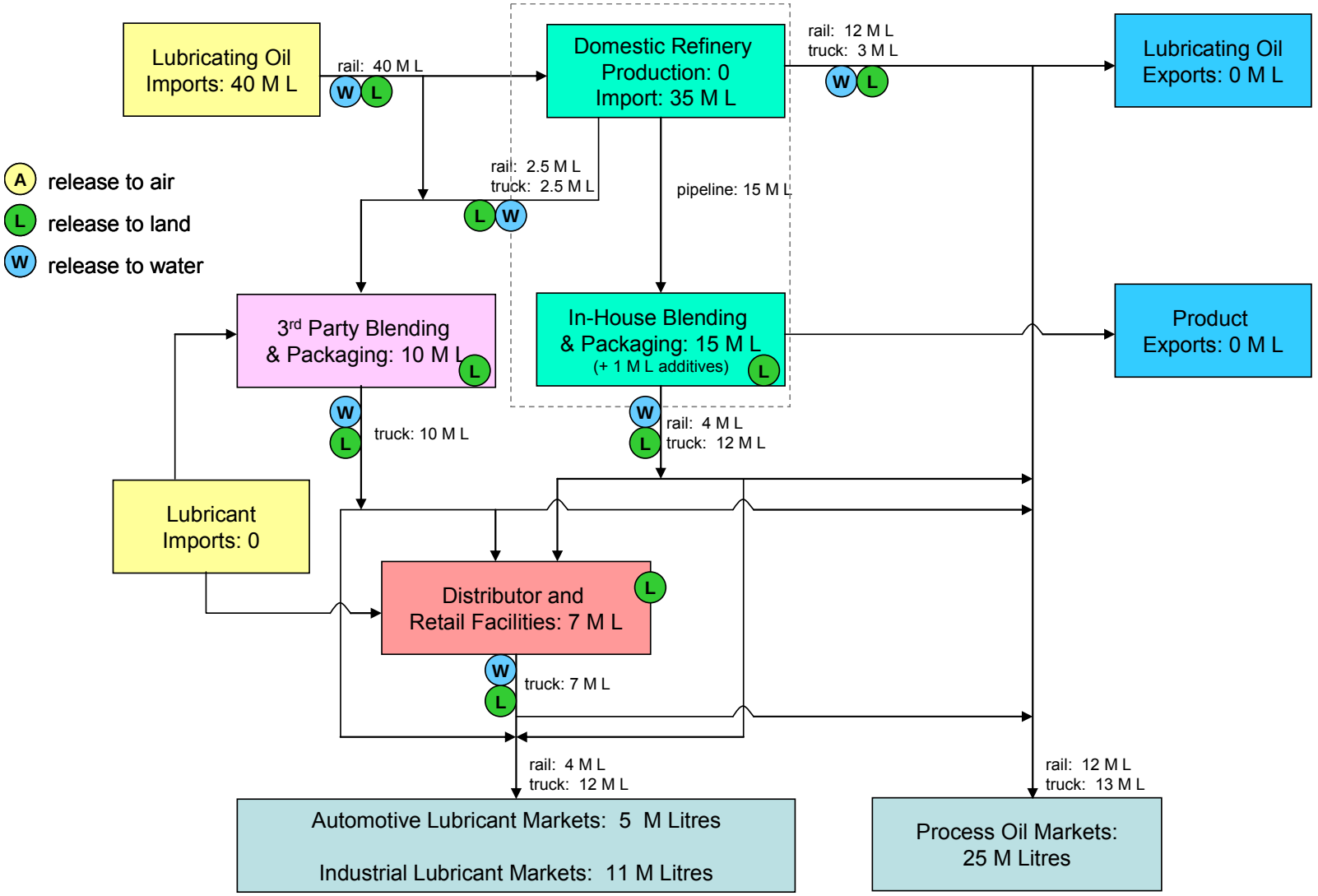


Figure 6. API Group I Oil: Potential Release Points

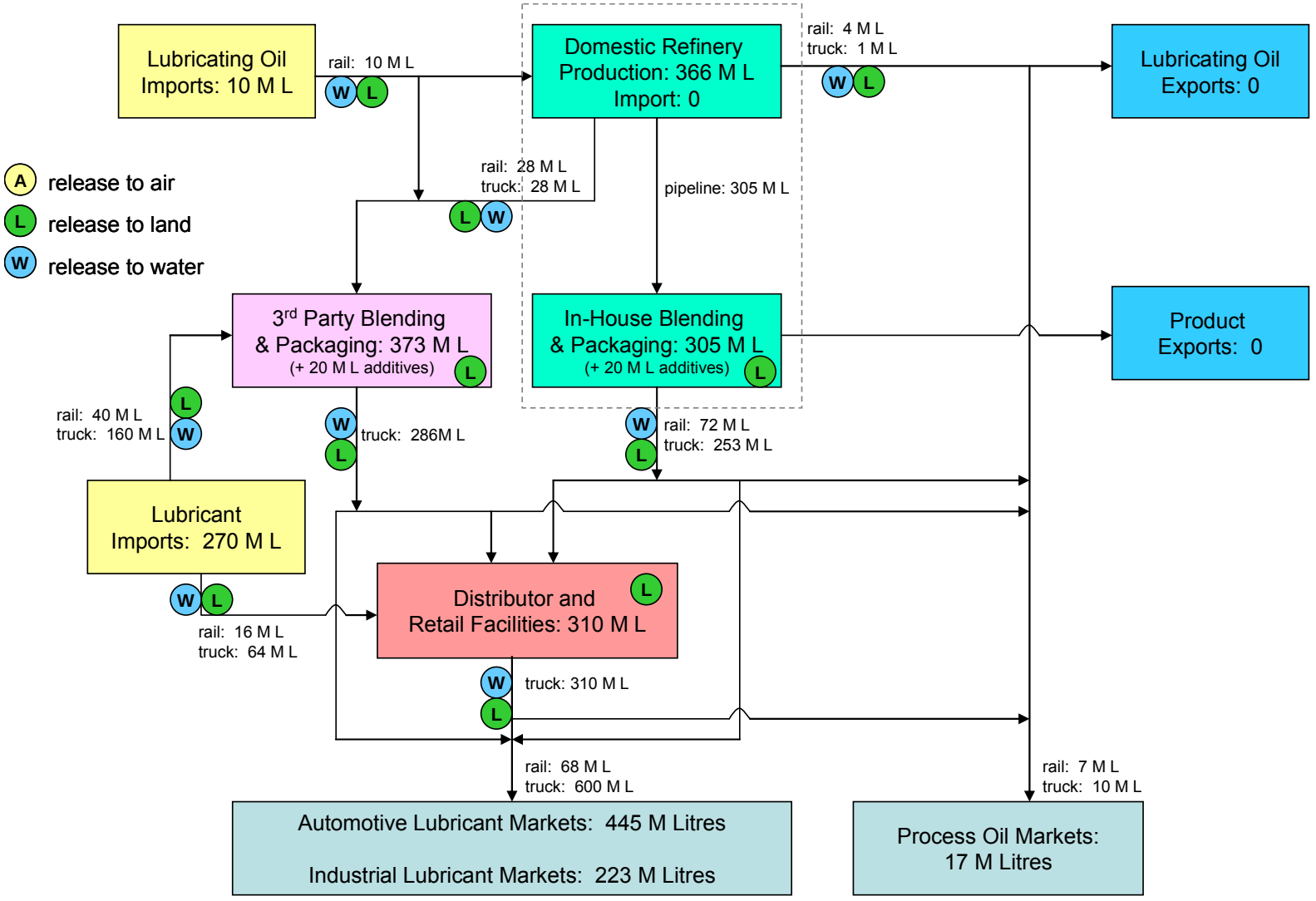
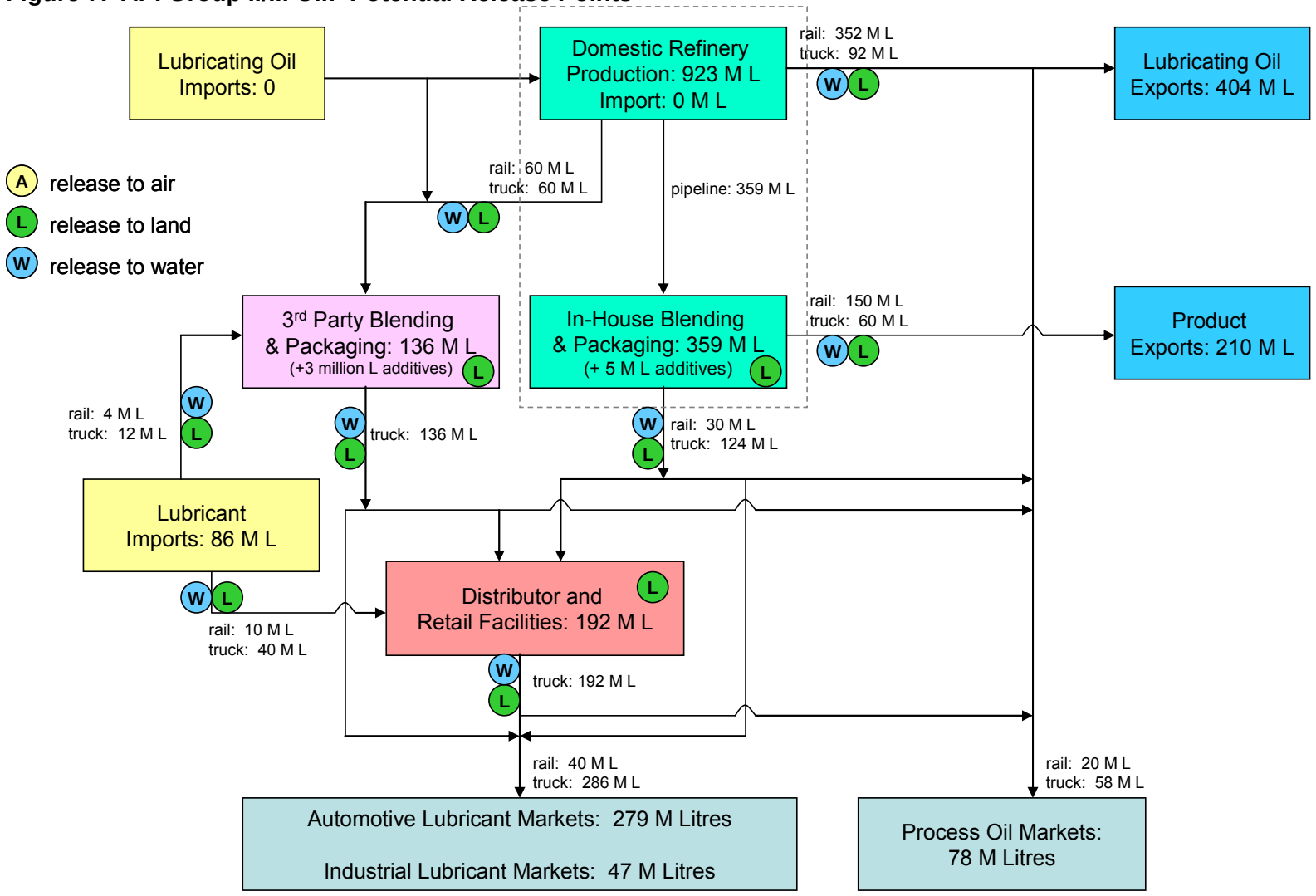


Figure 7. API Group II/III Oil: Potential Release Points



2.7.1 End of Use

The end of use disposition of each type of lubricating oil, as defined in Table 2, can be estimated by factoring the amount of each type of base oil used by estimates of oil disposition, for each lubricant application.

Uncontrolled dispersions and land filled quantities are considered as representing the level of environmental releases. Most of these releases are expected to result in exposure to land. However, a significant proportion of leaks and spills attributed to on-highway automotive lubricants (mainly engine oils) and marine lubricants will have an impact to water. For automotive lubricants, leaks on paved roadways in urban areas are known to end up in municipal sewage systems.

Most naphthenic oils are either lost or recycled as indicated in Table 8. The fate of naphthenic oils is impacted mainly by their use as process oils and metalworking fluids since in these applications, oil leaves the manufacturing facility along with the manufactured goods, and therefore are assumed to eventually dissipate to the ground or be land filled. The other applications of naphthenic oils are electrical oils, transmission fluids and compressor/refrigeration oils, and most of these products are recycled when used.

Table 8. End of Use Disposition of Naphthenic Lubricating Oil

		Volume, M Litres	% of Total
Recycled, Reused, Disposed	**Collected and Recycled**	9.5	23%
	On Site Burning	1.2	3%
	Land filled	2.0	5%
	Explosives Manufacture	0.1	0%
	Subtotal	**12.8**	**31%**
Consumed in Use	**Consumed in Use**	**18.5**	**45%**
Uncontained Dispersions	**Spill/Leaks**	1.3	3%
	Improper Disposal	0.2	0%
	Reused / Consumed	0.3	1%
	Total Loss Applications	7.9	19%
	Subtotal	**9.7**	**24%**
Total		**41**	

Conventional Group I oils, shown in Table 9, are lost and recycled at rates that reflect overall levels for lubricating oils (Tables 6 and 7) since Group I oils are widely used across nearly all applications and sectors.

Table 9. End of Use Disposition of Group I Lubricating Oil

		Volume, M Litres	% of Total
Recycled, Reused, Disposed	**Collected and Recycled**	327	48%
	On Site Burning	111	16%
	Land filled	14	2%
	Explosives Manufacture	9	1%
	Subtotal	**461**	**67%**
Consumed in Use	**Consumed in Use**	**124**	**18%**
Uncontained Dispersions	**Spill/Leaks**	42	6%
	Improper Disposal	22	3%
	Reused / Consumed	17	3%
	Total Loss Applications	19	3%
	Subtotal	**327**	**48%**
Total		**668**	

API Group II/III oils (Table 10) are lost and recycled at rates that reflect overall levels for lubricating oils (Tables 6 and 7) since Group II/III oils are widely used across nearly all applications and sectors. The slightly higher level of in use consumption (23%) and total loss applications (5%) reflects the consumption of Group II/III oils in process oil applications.

Table 10. End of Use Disposition of Group II/III Lubricating Oil

		Volume, M Litres	% of Total
Recycled, Reused, Disposed	**Collected and Recycled**	197	49%
	On Site Burning	50	12%
	Land filled	9	2%
	Explosives Manufacture	4	1%
	Subtotal	**260**	**64%**
Consumed in Use	**Consumed in Use**	**91**	**23%**
Uncontained Dispersions	**Spill/Leaks**	15	4%
	Improper Disposal	10	2%
	Reused / Consumed	8	2%
	Total Loss Applications	20	5%
	Subtotal	**53**	**13%**
Total		**404**	

2.8 Human Exposure to Lubricating Oils

A summary of potential points of human exposure with for each type of lubricating oil through the supply and distribution chain is shown in Figures 9 – 11. Two classes of exposure are indicated – occupational, which includes employees working in an environment where lubricants and process oils are handled and consumed, and exposure to the general public.

Salient features of Figures 8 – 10 are as follows:

- Based on established occupational health and safety standards, potential for human exposure is generally low to medium throughout the supply chain.
- During lubricant use, the potential for human exposure is high for both the general public and sector employees based primarily on the large consumer market for automotive lubricants and the hands-on nature of the automotive servicing industry.
- For industrial and process oil markets, the potential for human exposure is low for the general public.
- For industrial oil applications, the potential for occupational exposure is considered high due to the hands on nature of equipment operation, as well as the potential for airborne oil mists in enclosed manufacturing facilities.
- For process oil applications, the potential for occupational exposure to lubricating oils is considered medium.

Figure 8. Naphthenic Oil: Potential of Human Exposure

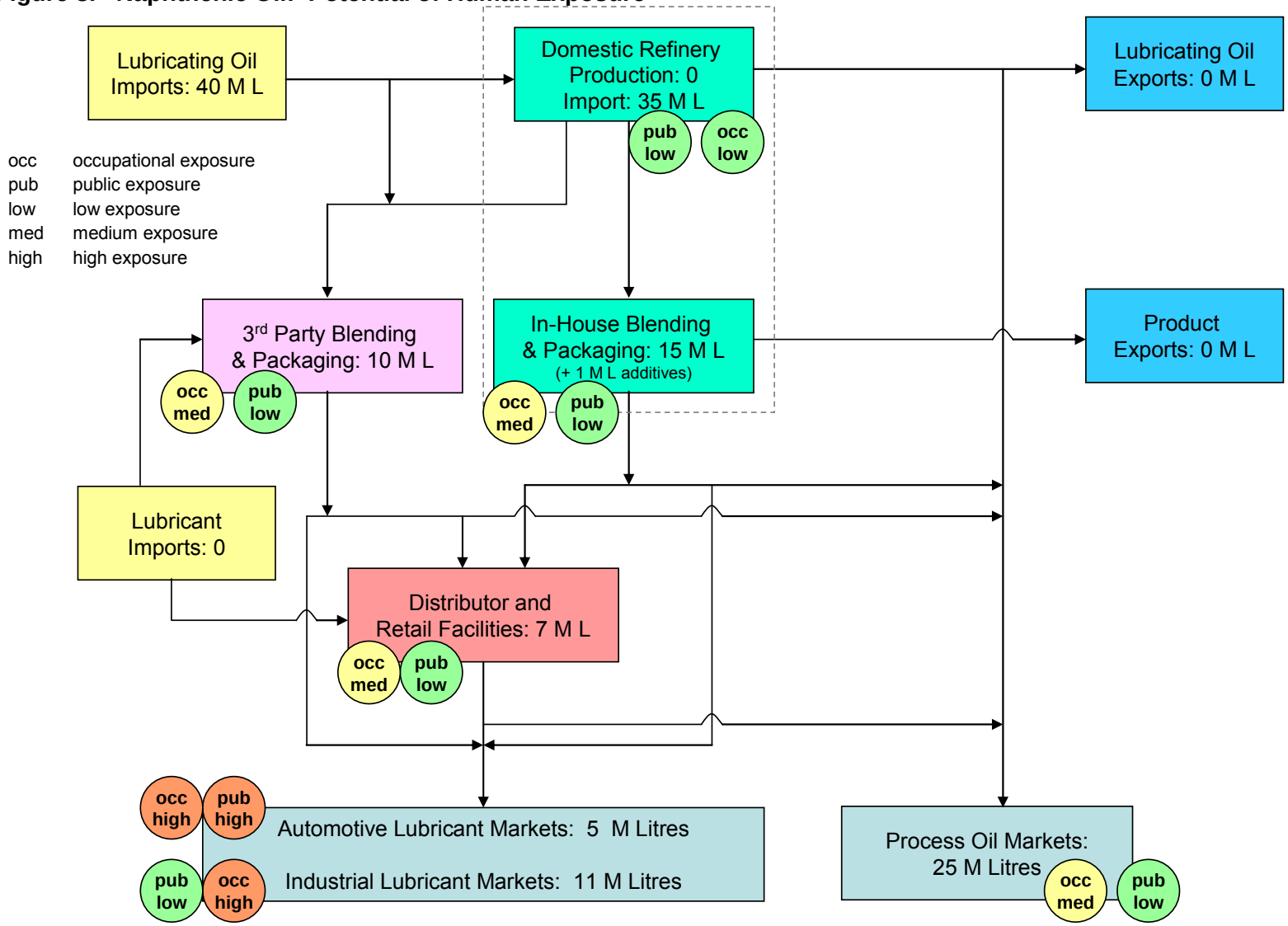


Figure 9. API Group I Oil: Potential of Human Exposure

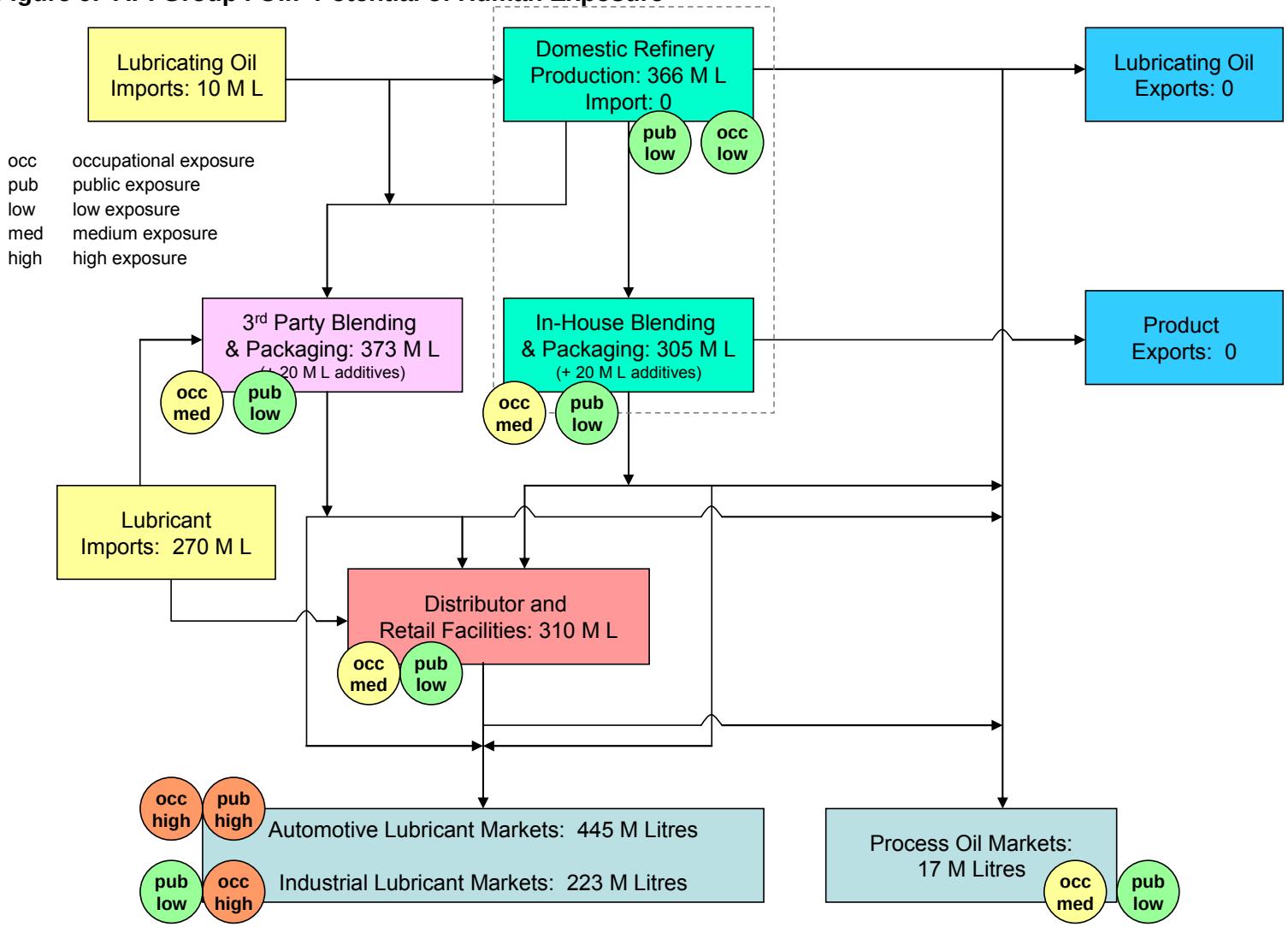
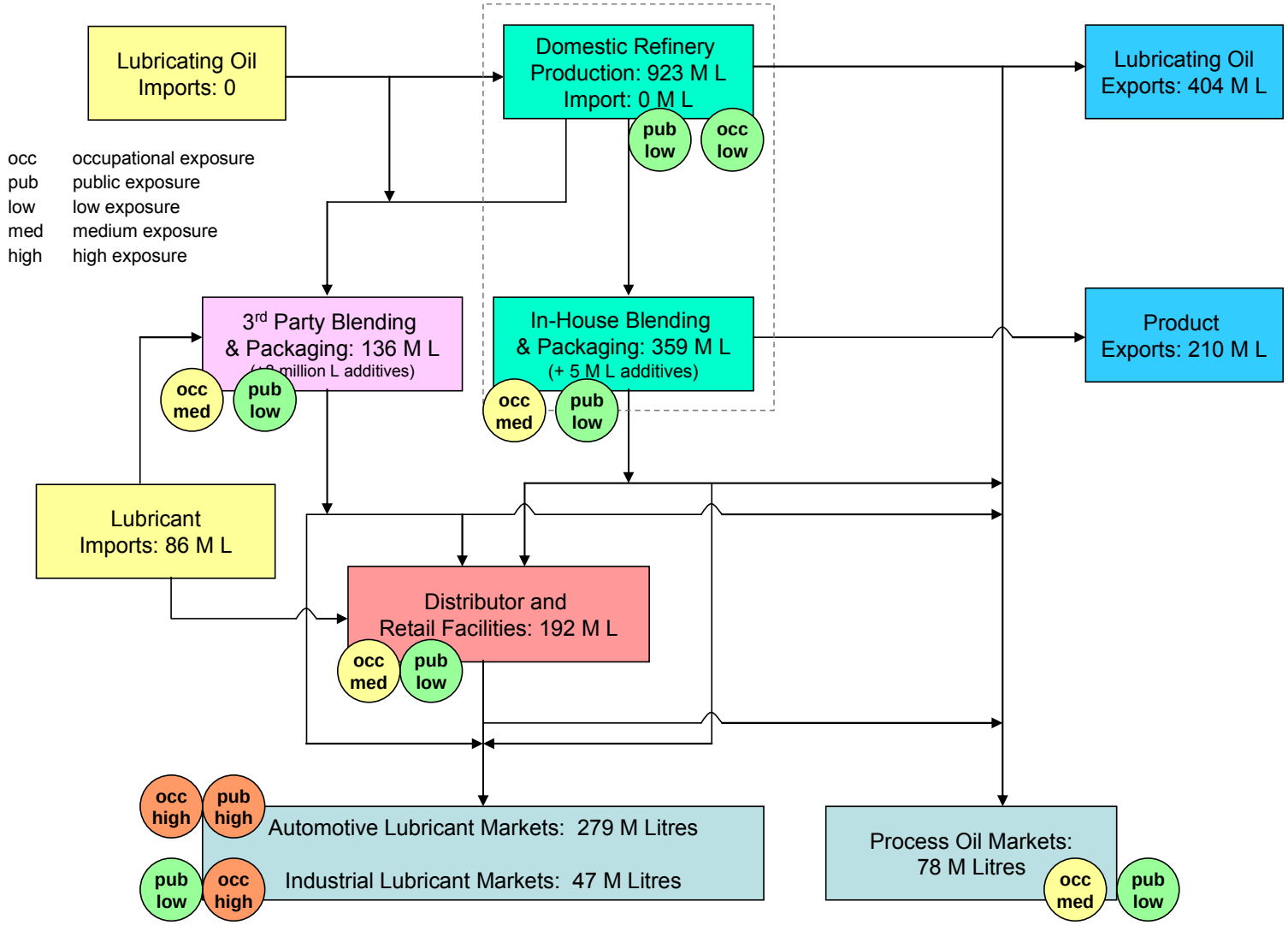


Figure 10. API Group II/III Oil: Potential of Human Exposure



3.0 Conclusions

As a result of this review, a series of lubricating oils identified by CAS RN's were identified as having entered or potentially entering commerce in Canada. From this point, a market analysis was completed that categorized the commercial lubricating oils, identified their production and supply chains, identified the markets and applications where they are used, and outlined their end of use disposition.

The substances identified by CAS RN were categorized according to industry standard designations published by the American Petroleum Institute (API). Due to the high level of interchangeability inherent in the lubricating oil industry, it was not possible to analyse the supply chain, market use, and disposition of each individual CAS RN. However, by grouping the substances by base oil classifications, a reasonable series of analyses of trends was completed.

Key findings of this study are summarized below.

- The lubricating oil industry in Canada is approximately 1.13 billion litres annually. This volume includes both additized and unadditized lubricating oils. The main markets are automotive lubricants (724 million litres), industrial lubricants (286 million litres) and process oils (120 million litres)

- The market use analysis of each type of lubricating oil determined that API Group I oils, which are conventionally refined paraffinic oils, are widely used in most lubricant and process oil applications. API Group II and Group III oils are produced using more extensive levels of hydrotreating and hydrocracking, and while they can also be used in virtually every lubricant and process oil application, there is a predominance of Group II and Group III oils used in high performance motors oils and automatic transmission fluids.

- Naphthenic oils, which have lower paraffin content, are imported for use in specific applications that include automatic transmission fluids, compressor and refrigeration oils, metalworking fluids, and electric insulating oils.

- The supply chain analysis identified low potential of release to the environment or exposure to human health. This is due to the fact that lubricating oils are shipped, transferred and stored in for-purpose facilities with established safe handling practices, and spill containment. Any risks associated with transportation would be related to unusual events, and not related to any specific transportation practices related to lubricants.

- Analysis of the end of use disposition of lubricating oils determined that over 50% of all lubricants used in Canada are recycled. However, nearly 14% of used lubricants (156 million litres) is lost or disposed of during use via spills, leaks, and total loss applications and represent environmental releases to land and water.

- A primary path of environmental release of used lubricants is uncontained leaks from the automotive sector, which includes cars, trucks, and off-highway equipment. On-highway vehicles are the largest contributor simply due to the number of vehicles in operation and the fact that leaks on asphalt surfaces in urban areas end up in municipal sewage systems.

- The potential for human exposure to lubricating oils during use is high based on the wide range of applications of oils and lubricants for consumer products. However, the level and frequency of exposure is considered low.