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Used Oil Management in Canada : Existing Practices and Alternatives

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August 1989

USED OIL MANAGEMENT IN CANADA: EXISTING PRACTICES AND ALTERNATIVES

by Monenco Consultants Ltd.

for the

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Ce rapport est aussi disponible en français sous le titre "Gestion des huiles usées au Canada : situation actuelle et différentes options," à l'adresse ci-dessous.

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ABSTRACT

The used oil generated in Canada each year is the largest single source of liquid organic hazardous wastes in the country. To reduce these volumes, Environment Canada encourages re-use and recycling of used oils as a first principle, and where necessary, proper treatment and disposal. Wherever practicable, used oils should be recovered as lubricants or for use as supplementary fuels under controlled combustion conditions.

To facilitate this process, the subject of used oil management in Canada was researched and this report on existing practices and alternatives was drafted to serve as a background document for developing programs and controls within various Canadian jurisdictions.

RÉSUMÉ

Les huiles usées produites chaque année représentent la plus grande quantité de déchets liquides organiques dangereux au Canada. Afin de diminuer le volume de ces huiles, Environnement Canada favorise principalement la réutilisation et le recyclage des huiles usées et, au besoin, un traitement et une élimination appropriés. Les huiles usées devraient être récupérées pour leur pouvoir lubrifiant ou être utilisées comme combustibles d'appoint dans des conditions de combustion contrôlées, dans la mesure où ceci est réalisable.

En vue de faciliter ce mécanisme, on a entrepris des recherches sur la question de la gestion des huiles usées au Canada et le présent rapport a été rédigé pour servir de document de base à l'élaboration de programmes et de moyens de contrôle au sein de diverses juridictions canadiennes.

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- Mr. Anil Somani (Project Manager);
- Mr. Ching Lee (Waste Management Engineer);
- Mr. Brian Geddes (Waste Management Engineer);
- Mr. Kurt Hansen (Waste Management Engineer); and
- Mr. Don Davies (Report Editor).

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SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

Environment Canada and provincial environmental regulatory agencies are establishing guidelines and regulations for the management of hazardous and other wastes in Canada. The management of used oil is particularly important because of the large quantities generated and their potential for recycle. Approximately 967 x 10^6 L of lubricating and other oils were sold in Canada during 1986. About 425 x 10^6 L of this volume could be recovered and recycled. However, less than half of this recoverable volume is projected to be recycled by rerefining, burning and road oiling. Remaining quantities are disposed of at source, in landfills or sewer systems, applied to unpaved roads as a dust suppressant or burned in an uncontrolled manner.

This study was designed to review used oil handling techniques in Canada, discuss environmentally sound alternatives, and present a recommended Code of Practice for the management of used oils. Major emphasis was given to the identification and implementation of recovery, reuse and recycling methods, and the economic implications of such initiatives.

1. **Used Oil Definition.** Used oil is an oil from industrial and non-industrial sources which has been acquired for lubricating and other purposes and has become unsuitable for its original purpose due to the presence of impurities or the loss of original properties. Used oil includes: lubricating oils (engine, turbine or gear); hydraulic fluids (including transmission fluids); metalworking fluids (including cutting, grinding, machining, rolling, stamping, quenching and coating oils); and insulating fluid or coolant (e.g., transformer fluid).

Used oil does not include oils derived from animal or vegetable fats, crude or fuel oils or wastes from petroleum refining operations.

2. **Existing Regulations.** There are currently no federal regulations dealing specifically with the management of used oils in Canada. However, the *Transportation of Dangerous Goods Act* and regulations under this act have been applied in some Canadian jurisdictions to the movement of used oils. The act and associated regulations provide for the documentation, safe handling and control of dangerous and hazardous materials during transportation.

Chlorobiphenyl regulations under the federal *Environmental Contaminants Act* limit PCB concentrations in oils used for dust suppression to 5 ppm. In addition, used oils with PCB levels above 50 ppm are classified as hazardous and must be handled, stored, treated and disposed of accordingly.

Federal regulations are forthcoming for the control of hazardous waste landfilling. The criteria for these regulations would by and large prohibit the landfilling of used oil unless pretreated (i.e., solidified). Emission guidelines, similar to those proposed for municipal solid waste incineration, may also be issued for the burning of used oil.

At the provincial level, several jurisdictions control used oil handling and disposal through general regulations and guidelines. The scope of these regulations varies considerably from province to province.

3. **Used Oil Inventory and Disposition.** Table A provides estimated used oil volumes for the provinces and territories in 1986. The estimates are based on the assumption that 44% of virgin lubricating oils are recoverable as used oils (Proctor and Redfern Ltd. et al., 1984). Most of these oils are generated by the automotive and industrial sectors of the economy. The automotive sector includes all 'on-road' vehicles operated by the general public, government, commercial operations and industry. Industrial sector oils include lubricants used in hydraulic and circulation systems, turbines and industrial and aviation equipment.

Used oil generators do not normally maintain comprehensive documentation of disposal practices; therefore, accurate descriptions of used oil disposition in Canada are difficult to develop. A review of available data suggests the following breakdown is generally representative of the situation:

Practice	Percentage of Used Oils Directed to Practice
Re-refining	24
Burning, road oiling and other applications	17
Unknown practices (e.g., landfilling, incineration and indiscriminate dumping)	59

TABLE A ESTIMATED USED OIL VOLUMES IN CANADA DURING 1986

Jurisdiction	Lubricating Oil Sales ($x10^6$ litres)	Estimated Used Oil Volumes ($x10^6$ litres)
British Columbia	92	40
Alberta	108	48
Saskatchewan	47	21
Manitoba	33	15
Ontario	489	215
Quebec	141	62
Atlantic Provinces	54	24
Northwest Territories	2	1
Yukon Territory	1	0
Canada	967	426

4. **Used Oil Characterization.** During service, lubricating oils may become contaminated with metal particles from engine wear, gasoline from incomplete combustion, rust, dirt, soot and lead compounds from engine blowby (i.e., material that leaks from the engine combustion chamber into the crankcase) and water from blowby vapour. In addition, some of the additives in lubricating oils break down during use and form corrosive acids. Used oils are also subject to non-use related contamination resulting from improper segregation and handling. Contamination from chlorinated solvents and PCBs is related primarily to poor segregation practices (Franklin Associates Ltd., 1985). Typical used automotive oils with respect to physical properties and concentrations of metals and organics are shown in Table B.

5. **Used Oil Handling and Transport**

5.1 **Current Collection/Transport Practices.** The bulk of used oils in Canada are generated by the automotive and industrial sectors of the economy. In the automotive sector, used oils collected by service stations, vehicle fleet operators and the like are picked up by private oil collectors and stored for subsequent re-utilization or disposal. However, large numbers of used oil generators in the automotive sector generally do not

TABLE B CHARACTERIZATION OF USED AUTOMOTIVE OIL (from Franklin Associates Ltd., 1985; Rudolph, 1978; and PEDCO-Environmental Inc., 1984)

Parameter	Parameter Value
Gravity API @ 16°C	24.0
Viscosity (cm^2/s)	0.99
Pour Point (°C)	37
Flash Point (°C)	140
Heating Value (kJ/kg)	38 000
BS&W*, Vol. (%)	11.0
Sulphur (wt %)	0.43
Ash (wt %)	1.01
Arsenic (ppm)	5
Barium (ppm)	48
Cadmium (ppm)	3
Calcium (ppm)	1 850
Chromium (ppm)	7
Copper (ppm)	177
Iron (ppm)	1 025
Lead (ppm)	240
Magnesium (ppm)	559
Phosphorus (ppm)	1 250
Silver (ppm)	1
Tin (ppm)	58
Zinc (ppm)	480
Chlorinated Solvents (ppm)	
- dichlorodifluoromethane	20
- trichlorotrifluoroethane	160
- 1,1,1-trichloroethane	200
- trichloroethylene	100
- tetrachloroethylene	105
Total Chlorine (ppm)	1 600
Other Organics (ppm)	
- benzene	20
- toluene	380
- xylene	550
- benzo(a)anthracene	12
- benzo(a)pyrene	10
- naphthalene	330
- PCBs	5

BS&W - bottom sediment and water

contribute to used oil stockpiles. Small businesses, "do-it-yourself" oil changers and farms normally lack on-site collection/storage facilities and tend to dispose of used oils in the most convenient manner available.

In the industrial sector, individual generators produce relatively large used oil volumes which create an economic incentive to segregate and collect oils for reprocessing.

5.2 **Alternatives.** The proportion of used oils recovered in Canada could be increased through the development of provincial collection systems. These systems could be administered by 'collection authorities' who would encourage small volume generators to use local collection centres, provide subsidies to transporters as required to maintain adequate collection frequencies and ensure that the oils collected are re-utilized in an environmentally appropriate manner.

6. **Used Oil Reprocessing and Re-refining.** Reprocessing involves the application of relatively simple physical/chemical treatments such as settling, dehydration, flashing, filtration, coagulation and centrifugation to remove the basic contaminants in used oils. The objective is to clean the oil to the extent necessary for less demanding applications, not to produce a product comparable to virgin oil. Reprocessing is not feasible for mixed oils; therefore, segregation of used oil stocks at source is essential. Reprocessed oils are most commonly used in industrial applications.

Re-refining technologies are designed to fully restore the original usefulness of the oil. The commercially proven processes typically used for re-refining in North America are: acid/clay treatment; vacuum distillation/clay polishing; vacuum distillation /hydrotreating; and chemical demetallization/vacuum distillation/hydrotreating.

The distillation technologies are newer and generally more viable economically than acid/clay processes. The relative cost effectiveness of distillation stems from greater used oil recoveries and process flexibility and the generation of fewer troublesome by-products.

The environmental effects of re-refining are closely related to the nature and volume of these by-products. Acid/clay processes generate large volumes of acid sludge and spent oily clay which are becoming increasingly difficult to dispose of in conventional landfills. Other re-refining technologies also produce potentially harmful by-products and wastes (i.e., acid and caustic sludges, oily clay, spent caustic, process wastewaters) but typically at much lower volumes than acid/clay processes.

7. **Used Oil End Uses.** Used oils have traditionally been directed to a wide variety of end uses, including: burning as fuel in boilers, space heaters, cement and brick kilns, asphalt plants and diesel engines; dust suppression on unpaved roads; asphalt production; secondary lubrication; flotation oil; concrete form oil; pesticide carriers; weed killers; livestock pest control oil; cleaning agents; and vehicle undercoating.

These end uses differ from the used oil management practices of reprocessing and re-refining in that they generally do not recycle the lubricating value of used oils and are therefore less attractive from a resource conservation point of view.

Of all the alternatives listed, controlled burning is the only option for which sufficient data exists to characterize environmental risks as acceptably low. Cement kilns exhibit an inherent gas scrubbing action that traps most of the contaminated particulate generated when burning used oils. The particulate is ultimately retained in a relatively insoluble form in the portland cement. Similarly, utility boilers equipped with flue gas pollution control equipment retain most used oil contaminants in the solid residuals collected by the pollution control facilities. When burning used oils in boilers without pollution control equipment, oil quality must be controlled and the number of boilers in an area must be limited if ambient air quality standards are to be maintained. The burning of used oils in residential and commercial space heaters can compromise air quality, particularly if a large number of heaters are present in a given area.

8. **Used Oil Disposal.** Used oil disposal involves the use of facilities or repositories which do not utilize the oil's lubricating and/or heating value. Disposal has traditionally been popular for oils generated some distance from reuse markets, among individuals who change their own automotive oil and in areas where the environmental hazards associated with improper disposal are not generally recognized.

Available disposal options for used oil include: incineration; dumping in a sanitary landfill; solidification followed by disposal in an authorized hazardous waste landfill; landfarming; dumping into municipal sewer systems; and indiscriminate dumping.

Of these, burning in a hazardous waste incinerator or solidification followed by secure landfill disposal are the only desirable options from an environmental point of view. The remaining alternatives do not provide adequate control of environmental risks.

9. **Socio-economic Aspects of Used Oil Management.** The socio-economic analysis examined the potential social benefits generated by the direct income and direct employment effects of four used oil management practices. The analysis demonstrated that re-refining would generate more gross income effects and higher levels of gross

employment than the three other management alternatives (burning, road oiling and disposal). The analysis also showed that these effects would be most pronounced in Ontario, Quebec and Alberta, where used oil volumes are relatively high.

The net income and employment effects of the four used oil management practices were not quantified, although it was noted that re-refining, burning and road oiling would displace income and employment in other industries. Re-refining for example, would displace conventional lube oil refining to some extent. It was determined, however, that because re-refining involves considerably higher labour costs than refining, it would generate more income and employment for the same level of output.

CONCLUSIONS

1. Of the estimated 425×10^6 L of used oil generated in Canada during 1986, only about 30% are re-refined or burned in a controlled fashion as supplementary fuel. The remainder is utilized or disposed of in environmentally inappropriate ways.

2. The lack of comprehensive used oil collection systems has seriously limited the supply of used oils available for re-utilization.

3. Re-refining and reprocessing of used oils are the most desirable re-utilization options from an environmental and resource conservation point of view. Environmental effects are reduced by concentrating used oil contaminants in by-products which are relatively easy to control and the lubricating value of the original oil is conserved.

4. Of the available re-refining technologies, distillation processes (vacuum distillation/hydrotreating and vacuum distillation/clay) are more desirable economically and environmentally than the older acid/clay treatment technologies.

5. With adequate flue gas emission controls, used oils can be burned as supplementary fuel in cement kilns and boilers with acceptably low environmental risks.

6. Hazardous waste incineration and treatment/authorized hazardous waste landfilling can be used to dispose of used oil in an environmentally acceptable manner.

7. Common used oil utilization/disposal practices such as road oiling, landfilling of untreated used oil, sewer disposal, uncontrolled burning in small heaters and indiscriminate dumping generate environmental effects that are at best ill-defined, and at worst, a clear threat to air, soil, surface water and groundwater quality.

8. Re-refining generally provides a lower economic return on investment than controlled burning. The economic viability of re-refining is further compromised when world crude oil prices are low due to strong competition from virgin lube oil refiners and a limited availability of used oil feedstocks.

9. The disposal of used oil is the most costly management practice when it is done in an environmentally acceptable manner (i.e., incineration or solidification followed by disposal in an authorized hazardous waste landfill). In addition, used oil disposal is not attractive as it does not utilize the heating or lubricating resource value of used oil.

10. Re-refining generates more gross income effects and higher levels of gross employment than the used oil management alternatives of burning, road oiling and disposal.

RECOMMENDATIONS

The primary recommendation described herein is a proposed strategy that can be used by regulators to formulate provincial or regional approaches to used oil management. This discussion is followed by a summary of associated recommendations that should be considered in conjunction with this strategy.

1. **Formulation of Used Oil Management Strategies.** Provincial or regional used oil management strategies should consider the inter-relation of oil collection, transportation and utilization. Oils cannot be effectively managed if collection/transportation systems are inadequate or if environmentally acceptable uses are not available for the oils collected. A broad perspective must be maintained if all the required components of a used oil handling system are to be effectively implemented.

It is clear that some form of collectively funded and operated used oil collection/transportation system will be required if a substantial proportion of the oils generated in a province or region are to be recovered. This system should incorporate mechanisms designed to:

- encourage small volume oil generators to deliver their used oils to local collection centres;
- provide economic incentives for service station owners and other used oil storage equipment operators to make their facilities available to the general public;
- compel retail outlets selling lubricating oils to provide used oil collection facilities available to the general public;
- provide for the construction and operation of publicly available collection facilities in small municipalities and rural areas inadequately served by existing oil storage equipment;
- provide economic incentives to local used oil haulers to ensure adequate collection frequencies for the local collection centres;
- provide for the construction and operation of regional used oil storage facilities to be used for the accumulation of oils collected by local oil haulers;
- provide economic incentives to long distance used oil transporters sufficient to guarantee the delivery of oils from the regional transfer stations to centralized oil users;
- identify environmentally appropriate users for the oils collected; and
- coordinate the efforts of local and long distance haulers to ensure that used oil supplies match demand.

Governments should consider playing a leading role in the creation of a 'collection authority' whose mandate would be to implement and administer the mechanisms listed. In addition, this authority could assist in marketing products generated by used oil reprocessors. Public education programs could be developed to highlight the environmental and resource conservation benefits of used oil recycling and assuage fears that used oil products are inferior to virgin lube oils. This latter objective could be supported by lobbying various levels of government to adopt procurement policies that encourage the use of re-refined products.

A used oil collection authority would effectively function as a marketing board, in as much as it would control used oil supplies and to some extent their prices, within an entire province or region. As such, the authority could encourage re-refining activities by preferentially supplying reprocessors at a price tied in some way to world crude oil prices. Excess used oil supplies could be directed to environmentally acceptable burners (e.g., cement kilns, large utility boilers).

The scope of a provincial or regional used oil collection system should be established by reviewing the subsidy levels required for various system sizes. Geographic differences in used oil generation rates may be such that a province-wide system would necessitate subsidy levels judged to be unacceptably high. In this case, collection efforts should be concentrated in those areas generating the greatest volumes of used oil.

A used oil management strategy should incorporate disincentives for environmentally inappropriate practices. The extent of these limitations for a given area should be determined in part by the scope of local collection facilities. In areas adequately served by a used oil collection system, bans on road oiling, uncontrolled burning and other undesirable practices will fulfill environmental objectives and improve used oil recoveries by encouraging generators to use the collection services provided. For areas in which these services do not exist (e.g., rural areas and northern regions), road oiling and uncontrolled burning bans should be carefully evaluated. Bans in such areas may accomplish little more than the redirection of used oils to even more objectionable ends such as uncontrolled landfilling and indiscriminate dumping.

In summary, an effective used oil handling strategy requires a comprehensive collection network, environmentally appropriate end uses for the oils collected and management mechanisms to support the system economically and logistically and encourage used oil generators to make use of the facilities provided.

2. **Associated Recommendations.** Implementation of the following recommendations in conjunction with those embodied in the strategy described in the previous section should be considered.

1. Used oils should be segregated at source to minimize contamination.
2. Labels on lubricating oil containers should provide information to encourage consumers to return used oils to appropriate collection facilities.
3. Quantities of used oil greater than 20 L should be stored in clearly marked tanks or drums approved for that purpose.
4. Used oil storage areas and collection centres should be provided with signs encouraging users to avoid contaminating oil supplies.
5. Used oil transporters (except small volume generators transporting oils to local collection centres) should be licensed and should be required to follow the Transportation of Dangerous Goods Act regulations, including manifest and placard requirements.
6. Legislation should require immediate reporting of used oil spills and other discharges to appropriate authorities.
7. Transport vehicle tank interiors should be cleaned prior to initial use for used oil collection/transport purposes.
8. Re-refinery operators should be encouraged to construct new facilities using vacuum distillation processes (vacuum distillation/hydrotreating and vacuum distillation/clay) rather than acid treatment processes (acid/clay and extraction/acid/clay).
9. Used oil burning should be restricted wherever possible to cement kilns and industrial and utility boilers equipped with flue gas pollution control equipment. Legislation (guidelines) specifying permissible emission levels of metal and organic contaminants should be developed to ensure environmentally acceptable burning practices for used oil.
10. Used oil burning should be allowed in boilers not equipped with pollution control equipment only when used oils meet specified standards for maximum contaminant levels and minimum heating values and when the number of burners in a given area is low enough to maintain ambient air quality standards.
11. The disposal of used oil should be discouraged in favour of re-refining and controlled burning. Highly contaminated used oils which cannot be re-utilized should be disposed of by burning in a hazardous waste incinerator or by solidification followed by disposal to an authorized hazardous waste landfill.

1 INTRODUCTION

Environment Canada and provincial environmental regulatory agencies are establishing guidelines and regulations for the management of hazardous and other wastes in Canada. The management of used oil is particularly important because of the large quantities involved and their potential for recycling. This study was undertaken to review current used oil management practices in Canada, to describe environmentally sound alternatives, and to present a recommended Code of Practice for the management of used oils in Canada.

Statistics Canada reports estimated sales volumes for lubricating oils (which include other oils such as hydraulic and cutting oils) on a monthly basis. Annual estimated volumes from 1981 to 1986 have averaged about 900 million litres. It is projected from this study that 400 million (44%) of these 900 million litres are potentially recoverable as used oil which may be reused or recycled in some manner. Only 25% to 27% of the recoverable used oil, however, was recycled over that six-year period by re-refining (to restore its lubricating properties). From 15% to 20% of the recoverable used oil was burned as a supplementary fuel (to utilize its energy value). The remaining quantities (53% to 60% of the 400 million litres) of recoverable used oil were disposed of indiscriminately at source and into solid waste landfills and sewer systems, applied to roads as dust suppressants or burned in an uncontrolled manner.

The major emphasis of this study is to identify recovery, reuse and recycling methods, their implementation and their economic implications as they affect strategy to the management of used oils. The handling, transport, treatment and disposal of used oils are also addressed.

The recommended practices for managing used oils in Canada will provide guidance for the used oil industry and the general public to form the basis for developing programs and controls within various Canadian jurisdictions.

1.1 Objectives

The objectives of the study were to:

- provide an overview of the current used oil situation including quantities, legislation and present methods and practices of handling, transporting, reusing, recycling, treating and disposing of used oils in Canada;
- provide an assessment of present and best available technologies and practices for the management of used oils in Canada with an emphasis on the economic benefits of alternative strategies leading to a recommended practice for managing used oils in Canada; and

- provide a recommended "Code of Good Practice" for the management of used oils in Canada.

These objectives were met and the findings, conclusions and recommendations are contained in this report.

1.2 Sources of Information

Various sources were used to gather information including:

- technical information provided by Environment Canada;
- interviews with provincial and territorial environmental agencies;
- discussions with used oil industry representatives;
- discussions with the Petroleum Association for the Conservation of the Canadian Environment (PACE);
- contact with U.S. EPA and California waste management agencies;
- literature searches, including computer data base searches;
- in-house information relating to the treatment of used oils and the transport, handling, storage, treatment and disposal of hazardous wastes; and
- technical comments and information received from a number of federal, provincial and territorial environmental departments as well as private companies whose representatives reviewed the draft version of this report. This report incorporates information as a result of some of the technical comments and information.

1.3 Used Oil Definition

Used oil (as referred to in this report) is defined as an oil from industrial and non-industrial sources which has been acquired for lubricating or other purposes and has become unsuitable for its original purpose due to the presence of impurities or the loss of original properties.

Used oil does not include crude or fuel oils spilled onto land or water and wastes from petroleum refining operations. The following categories of used oil are discussed:

- lubricating oils (engine, turbine or gear);
- hydraulic fluids (including transmission fluids);
- metalworking fluids (including cutting, grinding, machining, rolling, stamping, quenching and coating oils); and
- insulating fluid or coolant (e.g., transformer fluid).

Used oils may be contaminated with inorganic compounds such as lead and/or organic compounds such as chlorinated solvents and polychlorinated biphenyls (PCBs). The chemical content and other properties of used oil generally determine its classification, i.e., whether or not it is a hazardous substance and a dangerous good as defined in Canadian legislation. For example, if used oil contains 50 ppm or more of PCBs, it is designated a hazardous waste in most Canadian jurisdictions.

1.4 Existing Regulations

Federal and provincial regulations, standards and guidelines relating to the management of used oils in Canada are summarized in Table 1.

1.4.1 Federal Regulations. Federal regulations do not exist to deal specifically with the management of used oils in Canada. The *Transportation of Dangerous Goods* (TDG) *Act* and regulations thereunder, however, may apply to the transportation of used oils. The TDG regulations require the documentation, proper handling and transportation of dangerous goods for international and interprovincial modes of transport. Most provinces have adopted the federal regulations for provincial transport of dangerous goods. The transportation of used oils contaminated with hazardous substances or those which are dangerous, will fall under the TDG regulations.

The TDG regulations define a hazardous substance as a product or substance included in Division 2 of Class 9 in List II of Schedule IV of the TDG Act. Hazardous environmental substances within this division and class (excluding those listed under the Environmental Contaminant Regulations (e.g., PCBs)), are only exempt from the regulations if they contain less than 0.01 weight percent (100 ppm) of each hazardous substance listed. Consequently, used oil could be classified as a hazardous substance, because it may contain in excess of 100 ppm of:

- lead;
- zinc;
- trichloroethane;
- trichloroethylene;
- benzene;
- toluene;
- xylene; and
- PCBs (greater than 50 ppm content).

The TDG regulations classify liquids or mixtures of liquids under Class 3 as dangerous and flammable if they have a flash point below 61°C. Consequently, used oil may be dangerous as it could have a flash point of less than 61°C.

Although substances which are transported for recycling are presently exempt from the TDG regulations, amendments currently under consideration will remove this exemption (pers. comm. Campbell, 1987).

TABLE 1 SUMMARY OF FEDERAL AND PROVINCIAL REGULATIONS RELATING TO USED OILS

Jurisdiction	Regulatory Document	Description
British Columbia		- no specific used oil legislation
	Waste Management Act Special Waste Regulation 1988, Amended 1989	- "waste oil" is a special waste and means greater than 3% by weight of oils in a waste which are unsuitable for their original purpose
		- waste oil can be used in pavement, for road dust suppression, and as a fuel provided certain specifications are met
		- transportation: must be manifested for greater than 100 L; any facilities storing more than 50 000 L must have a permit
Alberta		- no specific used oil legislation
	Hazardous Chemicals Act Hazardous Waste Regulation 505/87	- waste lubricating oil intended for reuse, reprocessing or recycling is exempt from the Act and regulation
	Department of Labour Act Regulation 127/71	- requires the installation of oil and grease interceptors on waste outlets of all public garages
Saskatchewan		- no specific used oil legislation
	Environmental Spill Control Regulation	- accidental release of used oil must be reported to the Spill Response and Control Section of Saskatchewan Environment
	Environment Spill Control Amendment Regulations, 1983	
Manitoba		- no specific used oil legislation
	The Environment Act Manitoba Regulation 156/80 Manitoba Regulation 97/88R	- regulates the storage and handling of gasoline and associated products (including used oils)
Ontario	*Environmental Protection Act*, Ontario Regulation 309 (Revised Regs. of Ontario, 1980, as amended to O. Reg. 464/85)	- requires all hazardous and liquid industrial wastes generated in Ontario to be registered with the Ministry of Environment (MOE)
		- controls handling, transportation, storage, processing and disposal of wastes in Ontario
		- used oil not considered hazardous unless it contains contaminants listed in Schedules 1, 2A, 2B or 3 or exhibits characteristics of ignitibility, corrositivity, reactivity or leachate toxicity
		- exempts used oil from service stations/facilities having a written contract with a licensed carrier from registration and manifest requirements
	Ontario Regulation 11/82	- controls storage of oil containing PCBs at concentrations greater than 50 ppm
		- controls treatment and destruction of oil containing PCBs at concentrations greater than 50 ppm
	Guideline for the Handling and Disposal of Selected Liquid Wastes from Retail Motor Vehicle Serving Facilities	- used oil generated at the station to be stored in a tank specifically designed and used exclusively for that purpose
		- used oil not to be used in combustion systems unless approval obtained
		- dumping of used oil into sewers, drains and the natural environment prohibited
Quebec	Règlement sur les déchets dangereux (Hazardous Waste Regulation, 1985)	- regulates handling, storage, transport and disposition of hazardous waste including spent lubricating or cutting oil and spent hydraulic oil
		- prohibits road oiling for dust control or burning used oil other than for energy requirements of an industry or greenhouse
		- permits used oils with 3 ppm or less of PCBs to be burned in greenhouses provided certain operating conditions are met
	Guide for the storage of Hazardous Wastes and Management of Used Oil - (1985)	- sets maximum standards for certain contaminants in used oil intended for burning and for other uses including recycling

TABLE 1 SUMMARY OF FEDERAL AND PROVINCIAL REGULATIONS RELATING TO USED OILS (Cont'd)

Jurisdiction	Regulatory Document	Description
Quebec (Cont'd)		- exempts used oil being reused (including burning for energy purposes) and recycled from hazardous waste regulations
		- requires certificate and/or permit for storage, transport, reuse, recycling, treatment and disposal
	Règlement sur les déchets solides (Regulation respecting solid waste, 1985)	- prohibits operator of a sanitary landfill from accepting non-solid waste
New Brunswick		- no specific used oil legislation
	Clean Environment Act (Petroleum Product Storage and Handling Regulations)	- requires license for storage facilities
		- requires approval for waste oil disposal method
Nova Scotia	Waste Oil Regulations (*Dangerous Goods and Hazardous Wastes Management Act*)	- requires licensing for waste oil collection, purchase, sale, use, reuse and recycling
		- prohibits the use of contaminated waste oil for dust suppression; "contaminated waste oil" is defined as containing concentrations in excess of these listed: PCB - 5 mg/L, total organic halogens (as Cl) - 1000 mg/L, arsenic - 5 mg/L, cadmium - 2mg/L, chromium - 10 mg/L, and lead - 100 mg/L
		- regulated activities - . requires analysis of waste oil prior to disposal, sale or transfer . requires that only licensed collectors be used except in cases where Director's approval is given . prohibits dilution of waste oil contaminated with PCBs or total organic halogens (in excess of concentrations specified above) without Director's approval * Director - person designated by the Minister
Prince Edward Island	Environmental Protection (Petroleum Storage and Tanks Regulations)	- no specific used oil legislation
		- requires registration for storage facilities
Newfoundland		- no specific used oil legislation
	Department of the Environment Act (Storage and Handling of Gasoline and Associated Products Regulations)	- requires licensing of facilities
		- requires record keeping in storage and disposal facilities
		- requires collection and separation of waste oil collected at service stations
Yukon Territory		- no specific specific used oil legislation
	Public Health Act	- regulates waste disposal locations and prohibits contamination of drinking water sources
Northwest Territories		- no specific used oil legislation
	Environmental Protection Act	- regulates spills and controls emission and disposal of contaminants
Canada	*Environmental Contaminants Act*, Chlorobiphenyl Regulation No.3	- sets 5 ppm as the maximum permissible concentration of PCBs in used oil applied to roads for dust suppression purposes
		- set a limit of 50 ppm for any release to the environment and for classifying oils as hazardous with respect to handling, storage, transport and disposal
	Transportation of Dangerous Goods Act and Regulations	- regulates the offering for transport, handling and transportation of dangerous goods for interprovincial and international shipment by all modes; responsibility for transportation within provincial borders is under provincial jurisdiction
	Fisheries Act	- deposits of deleterious substances into sea and inland waters are prohibited (used oil is a deleterious substance)
	Migratory Birds Convention Act and Regulations	- deposit of oil in or near waters and on ice frequented by birds is prohibited
	Ocean Dumping Control Act	- crude oil, and its wastes, petroleum products/residues and any mixture of these are prohibited substances for which a dumping permit cannot be granted

Chlorobiphenyl regulations under the federal *Environmental Contaminants* (EC) *Act* control the maximum concentrations of polychlorinated biphenyls (PCBs) released to the environment. A maximum PCB content limit of 5 ppm is prescribed for used oils applied to roads for dust suppression while a maximum PCB content of 50 ppm is prescribed for any other release. Used oils containing 50 ppm or more PCBs are classified as hazardous and must be handled, stored, treated and disposed of accordingly.

1.4.2 **Provincial Regulations.** Used oil handling and disposal is controlled through provincial regulations and guidelines. In Alberta, under the Hazardous Chemicals Regulation, re-used, reprocessed or recycled waste lubricating oil is not considered a hazardous waste provided it is recycled in an acceptable manner. Ontario and Quebec currently have the most comprehensive requirements pertaining to used oils.

Used oil in Ontario is controlled primarily by Regulation 309 under the Environmental Protection Act. The Act regulates the handling, transportation, storage, processing and disposal of hazardous and liquid industrial wastes. Used oil is included in the categories of wastes that must be registered and disposed of at licenced facilities. Used oil from retail motor service stations does not require registration provided the operator has a valid contract with a licenced waste carrier. Guidelines for the approval of vapourizing type burners fired with used industrial oil (from diesel engines and hydraulic and transmission equipment) are in place. A specification for waste-derived fuels is currently under development. Used oil may be used on roads for dust suppression provided the oil does not originate from electrical equipment and provided the oil does not contain more than 5 ppm of PCBs. Road oiling in Ontario is currently under review due to the potential water pollution problem of this practice.

In Quebec, used oil is regulated under the provincial Hazardous Waste Regulation (1985), which specifically lists "spent lubricating or cutting oil and spent hydraulic oil" as hazardous wastes. Used oil cannot be applied to road surfaces for dust control purposes. It can be burned as a fuel to meet the energy requirements of an industry or greenhouse if the undiluted contents of selected metals, PCBs and halogens are less than the maximum levels of the specified used oil standards for burning (Table 2). Used oil recycling is considered the best disposal option. Other uses for used oil (e.g., wood preservation) must conform to used oil standards which are the same as those for burning with the exception of a much lower permissible PCB content (0.15 mg/L undiluted).

The remaining Canadian provinces and the Territories have no legislation specific to used oils.

TABLE 2 QUEBEC USED OIL REUSE/RECYCLING STANDARDS

Element	Maximum Concentration[a] (mg/L)		
	Specification I[b]	Specification II[c]	Specification III[d]
Arsenic (As)	5	5	5
Cadmium (Ca)	2	2	2
Chromium (Cr)	10	10	10
Lead (Pb)	100	100	100
PCBs	3	50	0.15
Total halogens	1 500	100	1 500
Flash point (minimum value)	38°C	38°C	38°C

a dilution to meet these standards is prohibited

b standards for used oil burned for energy requirements by any industry or greenhouse

c standards for greenhouse or industrial burners with 10 MW or more heating capacity

d standards for end-uses other than burning for energy recovery

2 USED OIL INDUSTRY AND CLASSIFICATION

2.1 Used Oil Inventory

2.1.1 Sales of Lubricating and Other Oils in Canada. Data on the sales of virgin oil lubricants are useful in estimating volumes of used oil generated. Lubricating oils and greases are materials of petroleum origin manufactured or sold for lubricating purposes, and other oils having special properties (apart from lubrication alone) such as brake fluids, automatic transmission oils, industrial cutting oils or coolants and rust preservatives (Statistics Canada, undated). Table 3 provides data on total lubricating oil sales in Canada for the years 1981 to 1986. The table shows a national annual average of about 900 million litres.

TABLE 3 LUBE OIL SALES IN CANADA*

	Sales ($x10^6$ litres)					
Jurisdiction	1981	1982	1983	1984	1985	1986**
British Columbia	111	100	94	86	87	92
Alberta	170	131	114	97	101	108
Saskatchewan	52	50	49	46	44	47
Manitoba	34	33	32	33	32	33
Ontario	422	358	388	442	446	489
Quebec	176	147	144	157	150	141
Atlantic Provinces	66	60	60	67	59	54
Northwest Territories	1.7	3.2	2.9	3.4	2.9	2.1
Yukon Territory	2.2	1.6	1.0	1.1	0.9	1.1
Canada	1 035	884	885	933	923	967

* from Statistics Canada (undated)
** 12-month period ending October 1986

Lubricating and other oil sales can also be broken down into specific user groups or sectors. Table 4 provides estimated sales distributions among the automotive, railway, marine, farm and industrial sectors in Canada and the United States. The table shows that at least 85% of the lubricating oils sold in Canada are used by the automotive and industrial sectors.

TABLE 4 PERCENTAGE OF LUBE OIL SALES BY SECTOR

	Reference		
	Canadian		American
Sector	Skinner (1974)	Rudolph (1978)	Franklin Associates Ltd. (1985)
Automotive*	40	36	40
Railway	5	3	3
Marine	2	1	2
Farm	8	3	3
Industrial**	45	57	52

* the automotive sector includes all "on-road" vehicles operated by the general public, government and industry

** the industrial sector includes industrial equipment, hydraulic and circulation systems, turbines and equipment used in aviation

2.1.2 Generation of Used Oils. Proctor and Redfern Ltd. et al. (1984) estimated that 44% of the roughly 900 million litres of lubricating oil sold annually in Canada is potentially recoverable as used oil. The remainder is consumed in use. The generation of used oils tends to follow the sectoral distribution of virgin lubricating oil sales (i.e., most used oils are generated in the automotive and industrial sectors).

The 44% used oil recovery estimate can be used to predict annual generation rates from Table 3. The resulting predictions are summarized in Table 5 to show a national annual average of about 400 million litres of potentially recoverable used oil. Similar estimates can be prepared for the various sectors involved in used oil generation. Table 6 presents estimated 1986 volumes by sector based on the assumption that 56%, 30% and 46% of lube oil sales in the automotive, industrial and other (i.e., railway, farm and marine) sectors, respectively, are recoverable for re-utilization (Proctor and Redfern Ltd. et al., 1984). The table shows annual potentially recoverable used oil volumes of 216, 131 and 67 million litres from the automotive, industrial and other sectors, respectively. A recent Canadian survey found that 1986 sales of lube oil for private cars and light trucks totalled 200 million litres (pers. comm., Freelay, 1987). This total represents 52% of the total automotive oil sales of 387 million litres (Table 6). The reason for the different numbers is the exclusion of oil sales for heavy trucks and commercial vehicles. This quoted survey also projected that about 55% of the 200 million litres were sold over the counter.

TABLE 5 ESTIMATED VOLUMES OF USED OIL GENERATED IN CANADA

Year	Lubricating Oil Sales ($x10^6$ litres)	Estimated Used Oil Volume ($x10^6$ litres)
1981	1 035	455
1982	884	389
1983	885	389
1984	933	411
1985	923	406
1986	967	425

TABLE 6 USED OIL GENERATED BY SECTOR DURING 1986

Sector	Assumed Percentage of Lube Oil Sales (%)	Estimated Lube Oil Sales ($x10^6$ litres)	Assumed Used Oil Recoverable From Sales (%)	Estimated Potential Recoverable Volume of Used Oil ($x10^6$ litres)
Automotive*	40	387	56	216
Industrial**	45	435	30	131
Others***	15	145	46	67
Total	100	967	-	414

* includes crankcase oils, transmission fluids, gear lubricants, etc.
** includes hydraulic fluids, turbine lubricants, aviation lubricants, etc.
*** includes the farm, railway and marine sectors

2.2 **Summary of Used Oil Disposition Practices.** Used oil generators normally do not maintain comprehensive documentation of disposal practices. Accurate descriptions of used oil disposition are therefore difficult to develop. Proctor and Redfern Ltd. et al. (1984) estimated for the year 1983 that 27% of used oil was re-refined, 12% was burned as supplemental fuel, 4% was used for road oiling, 5% was landfilled and the remaining 52% was unaccounted for. A provincial breakdown of Proctor and Redfern's estimated used oil disposition is provided in Table 7. The authors suggested that these percentages (Table 7) should be viewed as approximations only and further noted that a large portion of oil volumes unaccounted for are undoubtedly directed to the more undesirable end uses such as road oiling and uncontrolled burning. The Canadian percentages of used oil

TABLE 7 ESTIMATED USED OIL DISPOSITION IN CANADA DURING 1983 (adapted from Procter and Redfern Ltd. et al., 1984)

Jurisdiction	Total Used Oil Generated (1983) (x10^6 litres)	Used Oil Disposition (x10^6 litres) Road Oil	Fuel	Re-refined	Disposal (Landfill/ Incineration)	Unaccounted For
British Columbia	41	7.6 (19%)	NA	5.5 (13%)	11 (27%)	17 (41%)
Alberta	51	4.3 (8.4%)	.05 (0.10%)	8.6 (17%)	18 (35%)	20 (39%)
Saskatchewan	22	4.9 (22%)	0.53 (2.4%)	7.0 (32%)	10 (45%)	NA
Manitoba	14	NA	NA	NA	NA	NA
Ontario	173	31 (18%)	16 (9%)	5.2 (3%)	NA	120 (69%)
Quebec	64	3.5 (5.5%)	8.6 (13%)	17 (27%)	NA	35 (55%)
New Brunswick	9.2	0.73 (7.9%)	2.5 (27%)	.73 (7.9%)	.27 (2.9%)	5.3 (58%)
Nova Scotia	12	NA	9.0 (75%)	3.0 (25%)	NA	NA
Prince Edward Island	1.4	.31 (22%)	.07 (5%)	NA	1.1 (79%)	NA
Newfoundland	6.6	.23 (3.5%)	1.5 (23%)	1.1 (17%)	1.5 (23%)	2.3 (35%)
Northwest Territories and Yukon	NA	0.10	NA	NA	NA	NA

NA = not available

disposition quoted at the beginning of this section are inconsistent with the percentages which can be calculated from the data in Table 7 (e.g., 4% quoted for road oiling versus a calculated 13% from the Table 7 data). In addition, Table 7 shows a re-refined volume of 5.2 million litres for Ontario, while 91 million litres of re-refined oil from two re-refiners are quoted elsewhere in the report (Proctor and Redfern et al., 1984). In summary, the quoted percentages and the data listed in Table 7 are not very accurate.

The Canadian Association of Re-refiners (1987) estimated that approximately 170 million litres of the total volume of used oil generated in Canada are actually collected each year. Of this, about 100 million litres is re-refined and the remainder is burned or used in dust suppression or other applications. This suggests that about 24% of the total annual quantity of potentially recoverable used oil (i.e., the 414 million litres listed in Table 6) is presently re-refined and 17% is collected for other reuse practices.

In the United States, Franklin Associates Ltd. (1985) developed the following estimate for the disposition of collected used oils:

- re-refining (7%);
- burning as fuel (50%);
- road oiling (6%);
- non-fuel industrial reuse (3%);
- disposal by landfilling or incineration (14%); and
- dumping (20%).

The investigators determined that 45% of recoverable used oils are lost at source and not collected by used oil management systems. Franklin Associates Ltd. (1985) projected the following dispositions for the 45% of recoverable used oils: 18% are ultimately burned as fuel; 7% are used for road oiling; 9% are recycled at source; 22% are incinerated; and 44% are dumped indiscriminately.

The following estimates of used oil disposition are concluded to be the best available data for the current situation in Canada:

Practice	Percentage of Used Oils Directed to Practice
Re-refining	24
Burning, road oiling and other applications	17
Unknown practices (e.g., landfilling, incineration and indiscriminate dumping)	59

2.3 Characterization of Used Oil

2.3.1 Virgin Lube Oil Characteristics. To better understand the nature and origin of contaminants in used oil, it is essential that the characteristics of lubricating oil basestocks and additive packages be reviewed. Various additive compounds are blended into virtually all lubricating oils to improve the effectiveness of the lubricant and to extend its life. Additives usually comprise 10% to 20% by volume of finished lube products for most engine oils and therefore have a significant effect on lube oil composition (Weinstein, 1974). Heavy duty diesel engine oils contain from 15% to 30% (by volume) additives (pers. comm., Birze, 1987). The additives normally used along with descriptions of their composition, application and function are summarized in Table 8. Most additive packages contain a combination of several compounds. A typical additive package prepared for a gasoline engine oil is described in Table 9.

From Tables 8 and 9 it is clear that lubricating oil additives contain some hazardous constituents (e.g., barium (Ba), zinc (Zn), lead (Pb) and aromatic organics). Additives can also increase concentrations of sulphur, chlorine, and nitrogen in lube oil. An analytical characterization of virgin lube oil is summarized in Table 10, which indicates that additives increase barium and zinc concentrations and produce slightly elevated lead levels. As magnesium is now used in lieu of barium for additives, finished lube oils and therefore, used oils, contain no barium (pers. comm., Stringer, 1987).

TABLE 8 COMPOSITION, APPLICATION AND FUNCTION OF LUBRICATING OIL ADDITIVES (from Skinner, 1974 and Franklin Associates Ltd., 1985)

Name of Additive	Composition	Application	Function
Corrosion Inhibitor	Zn dithiophosphates, dithiocarbamates, metal sulphonates, and sulphurized terpenes	- internal combustion engines, alloy bearings, automatic transmission fluid	- to react with metal surfaces to form a corrosion-resistant film
Rust Inhibitor	sulphonates, alkylamines, amine phosphates, alkenylsuccinic acids, fatty acids, and acid phosphate esters	- internal combustion engines, turbines, electric and mechanical rotary machinery, fire-resistant hydraulic fluids	- to react chemically with steel surfaces to form an impervious film
Antiodorant	perfumes, formaldehyde compounds	- with extreme pressure additives	- to mask odours
Antiseptic	alcohols, phenols, chlorine compounds	- with water added to oil-emulsions	- to inhibit microbial growth
Antioxidant	sulphides, phosphites, amines, phenols, dithiophosphates	- internal combustion engines, turbines, and rotary machinery	- to inhibit oxidation of oil
Antifoam	silicones, synthetic polymers, waxes	- same as rust inhibitors, excluding ball bearings	- to permit air bubbles to separate from oil
Detergent	sulphonates, phosphonates, phenates, alkyl substituted salicyclates combined with magnesium, zinc, calcium	- internal combustion engines, under steady load	- to neutralize acids in crankcase oils to form compounds suspended in oil
Dispersant	alkenyl succinimides, alkylacrylic polymers, ashless compounds	- internal combustion engines, at low temperatures and variable loads	- to disperse contaminants in the lubricant
Metal Deactivator	organic dihydroxyphosphines, phosphites and sulphur compounds	- internal combustion engines, turbines, electric motors, air compressors, hydraulic oils	- to form protective film on running surfaces to inhibit corrosion reactions
Colour Stabilizer	amine compounds	- when heat and oxidation darken oil	- to stabilize oil colour
Viscosity Index Improver	isobutylene polymers and acrylate copolymers	- internal combustion engines, electric motors, air compressors, hydraulic oils	- to retard loss of viscosity at high temperatures
Pour Point Depressant	polymethacrylates, polyacrylamides, alkylated naphthalenes and phenols	- internal combustion engines, gears, bearings, transmissions	- to prevent congealing of oil at low temperatures
Extreme Pressure Additives	organic compounds with sulphur, phosphorus, nitrogen, halogens, carboxyl or carboxalate salt	- internal combustion engines, turbines, motors, hydraulic oils, gears, rollers and ball bearings	- to form low-shear-strength film providing lubrication at startup and at high bearing loads
Antiwear Additive	chlorinated waxes, organic phosphates, lead naphthenate	- as above	- as above except for running condition
Tackiness Agent	polyacrylates and polybutenes	- gear enclosures from which oil must not drop	- to improve adhesive qualities of base oil
Emulsifier	surfactants, sulphonates, naphthenates and fatty acid soaps	- soluble cutting oils	- to reduce interfacial tension and permit formation of water-oil emulsion

TABLE 9 TYPICAL FORMULATION OF GASOLINE ENGINE OIL (from Weinstein, 1974)

Ingredient	Percent of Volume
Base Oil (solvent 150 neutral)	86
Detergent Inhibitor (ZDDP-zinc dialkyl dithiophosphate)	1
Detergent (barium and calcium sulphonates)	4
Multi-functional Additive (dispersant, pour-depressant, viscosity improver-polymethyl-methacrylates)	4
Viscosity Improver (polyinsobutylene)	5

TABLE 10 HAZARDOUS CONSTITUENTS IN VIRGIN LUBE OILS (from Franklin Associates Ltd., 1985)

	Concentration Range (ppm)			
	Virgin Base Stock[a]		Finished Lube Oil[b]	
Constituent	Low	High	Low	High
Metals				
Barium	0	1.0	1.2	162
Cadmium	<0.2	0.8	0	-
Chromium	0	0.05	0	-
Lead	0	1.0	0	3
Zinc	1.0[c]	1.0[c]	359	2 440
Total Chlorine	-	-	-	155[d]
Benzo(a)pyrene	0.03	0.28	0.03[e]	0.28[e]

a no additives; data developed from only five sample tests
b containing additive packages; data from several limited analyses
c only two samples analyzed for zinc, each showing levels of 1 ppm
d only one sample analyzed for total chlorine
e not known if additives present in analyzed samples

2.3.2 Used Oil Composition. During service, lubricating oils may become contaminated with metal particles from engine wear, gasoline from incomplete combustion, rust, dirt, soot and lead compounds from engine blowby (i.e., material that leaks from the engine combustion chamber into the crankcase) and water from blowby vapour. In addition, some oil additives break down in use and subsequently form corrosive acids. Used oils are also subject to non-use related contamination resulting from improper segregation and handling. Contamination with chlorinated solvents and PCBs is thought to be primarily related to poor segregation of used oils at source or during collection (Franklin Associates Ltd., 1985).

Physical Characteristics. Some of the physical characteristics of used oils are summarized in Table 11. The following observations can also be made:

- the measured flash point of used oil ranges from 17°C to 290°C compared to 150°C to 200°C for virgin lube oil; the presence of contaminants influences the ignitability of the oil; Transport of Dangerous Goods Regulations classifies a waste as "dangerous" if it has a flash point <61°C; Table 11 indicates that many of the oil samples had a measured flash point below 61°C; these low flash points are due to the presence of chlorinated and organic solvents and gasoline;
- most used oils contain some bottom sediment and water (BS&W), usually less than 10% by volume; samples containing more than 10% BS&W are usually contaminated by emulsified oils, tank bottoms, or washdown fluids;
- some of the used oil samples are less viscous than gasoline, which indicates a high solvent content (note: gasoline has a dynamic viscosity of 0.05 cm^2/s at 38°C, whereas some heavy machine oils have viscosities exceeding 20 cm^2/s); and
- pure lube oil typically has a heating value somewhat higher than 46 000 kJ/kg (Franklin Associates Ltd., 1985); Table 11 shows that the heating values of the used oil samples range from 9 630 to 53 600 kJ/kg, with the lower heating values due to the presence of water and other inorganic solid contaminants in the oil.

TABLE 11 SUMMARY OF PHYSICAL CHARACTERISTICS OF USED OILS (from Franklin Associates Ltd., 1985)

Parameters	Number of Samples	Range Low	Range High	Mean	Median
Flash point (°C)	289	17	290	99	-
Bottom sediment and water (%)	320	0	99	19	9
Water only (%)	36	0	67	11	5
Viscosity (cm^2/s at 38°C)	70	0.01	5.13	0.71	0.47
Specific gravity	48	0.67	0.98	0.89	0.89
Heating value kJ/kg	231	9 630	53 600	38 370	40 000

Hazardous Constituents. Table 12 characterizes used oils with respect to concentrations of 19 constituents, 17 of which are identified on the U.S. EPA's list of hazardous constituents (U.S. Federal Register, 1981 as cited in Franklin Associates Ltd., 1985). The mean concentrations reported in Table 12 are greatly distorted by a few high concentrations. The mean is in fact higher than the median for every constituent, which in this case is a better indicator of typical concentrations.

Trace metals of concern enter used oil from various sources. As mentioned earlier, lead originates primarily from the consumption of leaded gasoline in engines, whereas the bulk of barium and zinc concentrations are the result of oil additives. Cadmium and chromium enter used oil in trace amounts, primarily as a result of engine wear; however, some additives may also contain these metals. The source of arsenic in used oil has not been determined (Franklin Associates Ltd., 1985).

The lead concentrations reported in Table 12 are higher and more variable than those for other metals. These lead ranges are based on U.S. data collected between 1979 and 1983. They are expected to be fairly representative of past lead levels in Canadian used oils. Present lead levels in Canadian used oils are expected to be less than those shown in Table 12 due to the reduction of permissible lead levels in regular gasoline. The permissible lead level was reduced from 0.77 g/L to 0.29 g/L according to regulations under the *Canadian Clean Air Act*.

Other trace metals in used oils occur typically at lower concentrations than lead. Barium levels normally range between 50 and 500 ppm while cadmium concentrations are generally around 2.0 ppm and rarely exceed 10 ppm. Chromium and arsenic levels are similar, typically ranging from 3.0 to 30 ppm. Zinc is the only trace metal which exhibits concentrations close to those for lead. Zinc levels normally range from 100 to 1 200 ppm.

Chlorinated solvents are non-use related contaminants introduced into used oil through improper segregation and handling. There are five commonly detected chlorinated solvents including 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, dichlorodifluoromethane, and trichlorotrifluoroethane. Levels of contamination appear random, with the majority ranging from less than 100 to several thousand ppm.

The total chlorine levels reported in Table 12 provide an indication of the degree of contamination by potentially hazardous chlorinated substances. Available data indicates that total chlorine concentrations typically range between 1 000 and 5 000 ppm.

TABLE 12 CONCENTRATION OF POTENTIALLY HAZARDOUS CONSTITUENTS IN USED OILS (from Franklin Associates Ltd., 1985)*

Parameter	Number of Samples Analyzed	Samples with Detected Contaminants No.	Samples with Detected Contaminants %	Mean Concentration** (ppm)	Median Concentration*** (ppm)	Concentration at 75th Percentile*** (ppm)	Concentration at 90th Percentile*** (ppm)
Metals							
Arsenic	537	135	25	17	5	5	18
Barium	752	675	89	132	48	120	251
Cadmium	744	271	36	3.1	3	8	10
Chromium	756	592	78	28	6.5	12	35
Lead	835	760	91	665	240	740	1 200
Zinc	810	799	98	580	480	872	1 130
Chlorinated Solvents							
Dichlorodifluoromethane	87	51	58	373	20	160	640
Trichlorotrifluoroethane	28	17	60	62 900	160	1 300	100 000
1,1,1-Trichloroethane	616	388	62	2 800	200	1 300	3 500
Trichloroethylene	608	259	42	1 390	100	200	800
Tetrachloroethylene	599	352	58	1 420	106	600	1 600
Total Chlorine	590	568	96	5 000	1 600	4 000	9 500
Other Organics							
Benzene	236	118	50	961	20	110	300
Toluene	242	198	81	2 200	380	1 400	4 500
Xylenes	235	194	82	3 390	550	1 400	3 280
Benzo(a)anthracene	27	20	74	71	12	30	40
Benzo(a)pyrene	65	38	58	25	10	12	16
Naphthalene	25	25	100	475	330	560	800
PCBs	753	142	19	109	5	15	50

* results determined from the analyses of 1071 used oil samples
** calculated for detected concentrations only
*** for the purposes of determining median and percentile concentrations, undetected levels were assumed to be equal to the detection limit

Aromatic solvents such as benzene, toluene and xylene are found in used oils as a result of the inherent characteristics of virgin oils, oil use and mixing with spent solvents. Table 12 shows that toluene and xylene concentrations normally range from 500 to 5 000 ppm while those for benzene are lower, typically ranging between 100 and 300 ppm.

Polynucleated aromatics (PNAs) (benzene(a)anthracene, benzo (a)pyrene and naphthalene) are present in both virgin and used lubricating oils. However, they seem to become more concentrated in the latter by contributions from gasoline or diesel fuel and combustion products.

PCB contamination of used oils is less significant than it was when PCBs were more widely used. Table 12 shows that of the 753 automotive and industrial used oil samples, only 19% had detectable PCBs. These oils contained an average PCB level of 109 ppm, indicating that several of them probably had unusually high concentrations of PCBs (i.e., up to 3 800 ppm).

2.4 Classification of Used Oil

Used oils are most often classified into the automotive and industrial categories described previously. These categories can be further subdivided according to the following oil types:

- lubricants;
- hydraulic fluids;
- metalworking fluids; and
- insulating fluids.

Used oil generation data for the United States by major oil type are presented in Table 13. The table shows that more than 85% of the used oils generated are lubricants or hydraulic fluids. The Canadian distribution of major oil types is likely similar to that shown in Table 13.

TABLE 13 USED OIL QUANTITIES IN THE UNITED STATES BY MAJOR OIL TYPES[ae] (from Franklin Associates Ltd., 1985)

Major Oil Type	Virgin Oil Sales[a] ($x10^6$ litres)	Assumed Used Oil Generation Factor	Used Oil Generated ($x10^6$ litres)	Percentage by Used Oil Type
Lubricants[b]	5 300	0.53	2 800	62%
Hydraulic Fluids[c]	1 700	0.64	1 100	24%
Metalworking Fluids[d]	620	0.77	480	11%
Insulating or Electric Fluids[e]	290	0.27	80	2%
Totals	7 910		4 460	99%

a 1983 data
b including vehicle engine oils, industrial engine oils and turbine circulation gear, refrigeration and compressor oils
c including hydraulic oils from vehicles and industrial equipment
d including metal removing/forming/treating/protecting oils
e essentially transformer oils

Characterization data for the major used oil types are also available in the literature. The concentrations of a number of potentially hazardous contaminants in used gasoline and diesel engine oils, hydraulic oils, and cutting or machine oils are compared in Table 14. Gasoline and diesel engine oils are major lubricants, while cutting and machine oils are common metalworking fluids in the iron and steel fabrication industry.

The limited data for used diesel engine oils suggest that lead concentrations in gasoline engine oils are much higher than in diesel engines and the other two groups of industrial oils. This difference will likely diminish as leaded gasolines are phased out. Gasoline engine oils also appear to have higher concentrations of other metals than the other oil types. It should be noted, however, that the data for diesel engine oils are too limited to be conclusive.

Definitive conclusions regarding the organic contaminants in used oils are difficult to make given the limited analytical data available. It appears that benzo(a)pyrene, a carcinogen, is present at higher levels in gasoline engine oils than diesel oils. The high levels of total chlorine in metalworking and hydraulic oils are probably the result of mixing solvents with used oils (used engine oils would likely show similar results if tested). Thirty percent of the 13 metalworking oil samples tested had detectable PCBs, whereas none of the eight hydraulic oil samples showed the presence of PCBs.

Overall, Table 14 shows that used gasoline engine oils generally contain higher levels of contaminants than used diesel engine oils, and that used hydraulic oils are generally less contaminated than used metalworking oils. The presence of at least low levels of organic solvents and PCBs in all oil types indicates that both automotive and industrial generators do have a tendency to mix other materials with their used oils.

TABLE 14 COMPARISON OF POTENTIALLY HAZARDOUS CONSTITUENT LEVELS IN USED OILS BY SPECIFIC OIL TYPES (from Franklin Associates Ltd., 1985)

Parameter	Constituent Concentrations in Gasoline Engine Oils (ppm)		Constituent Concentrations in Diesel Engine Oils* (ppm)		Constituent Concentrations in Hydraulic Oils (ppm)		Constituent Concentrations in Cutting or Machine Oils (ppm)	
	Range	Median (n)	Range	Median (n)	Range	Median (n)	Range	Median (n)
Metals								
Arsenic	<0.4 to 17	<5 (44)	<5 to 5.9	<5 (5)	N/D	- (8)	N/D	- (12)
Barium	2 to 3 906	87 (138)	0.78 to 19	4.1 (5)	<0.5 to 56	3.1 (9)	<0.5 to 330	23 (29)
Cadmium	0 to 8.8	1.3 (86)	<0.5 to 1.4	0.88 (5)	<0.5 to 4	0.5 (10)	0 to 21	0.5 (39)
Chromium	0.3 to 50	7.7 (123)	0.86 to 3.8	1.5 (5)	<0.1 to 3	0.5 (10)	0 to 520	2 (39)
Lead	8.5 to 21 676	390 (87)	<5 to 78	13 (5)	<0.6 to 150	5 (10)	<0.01 to 3 500	16 (40)
Zinc	6 to 3 000	990 (142)	4.4 to 820	280 (5)	0.5 to 600	17 (10)	0.53 to 530	38 (41)
Chlorinated Solvents								
1,1,1-Trichloroethane	445	) Mean of 4 out of 18	200	200 (2)	<2 to 62 000	4 (8)	N/D	- (12)
Trichloroethylene	84	) samples which had	2 600	- (1)	<2 to 18	4 (8)	<4.1 to 26 000	15 (14)
Tetrachloroethylene	453	) detectable conc.	293	- (1)	<2 to 980	4 (8)	<2.2 to 2 40015(13)	
Dichlorodifluoromethane	N/M	-	N/M	-	N/M	-	N/M	-
Trichlorotrifluoroethane	N/M	-	N/M	-	N/M	-	100 000 to 300 000	10 000 (2)
Total Chlorine	N/M	-	N/M	-	100 to 24 600	200 (8)	<100 to 86 700	4 000 (14)
Other Organics								
Benzene	92	) Mean of 4 out of 18	21	- (1)	<2 to 100	4 (8)	N/D	- (12)
Toluene	1 374	) samples which had	1 960	- (1)	<2 to 6 300	9 (8)	<7 to 5 70015(14)	
Xylenes	1 289	) detectable conc.	1 817	- (1)	<2 to 700	7 (8)	<7 to 1 10070(14)	
Benzo(a)pyrene	11.7		1.3 to 1.7	1.5 (4)	N/M	-	N/M	-
Benzo(a)anthracene	N/M	-	N/M	-	N/M	-	N/M	-
Naphthalene	N/M	-	N/M	-	N/M	-	N/M	-
PCBs	N/M	-	N/M	-	N/D	- (8)	<5 to 3 800	5 (13)**

* although reported as diesel engine oils, some of these samples are believed to contain some gasoline engine oils (applies to metals only)

** only four samples showed detectable PCBs

n = total samples analyzed; N/D = not detected; N/M = not measured

3 USED OIL HANDLING AND TRANSPORT

3.1 Current Practices - Collection/Transport

There are presently between 15 and 25 major regional used oil collectors in Canada (Table 15). Some of these operations are limited to certain local areas while others are large interprovincial operators. Most of these collectors are also used-oil processors/utilizers such as re-refiners, burners, road oilers and waste management firms. These collection services are usually confined to urban and industrial areas. Used oil collection services in rural areas are quite limited due to the wide geographical dispersion of collection points and the small volumes of used oil generated. Depending on market conditions, collectors may pay for the used oil, take the oil for free, or charge the generator for the collection service (Proctor and Redfern Ltd. et al., 1984).

Used oils are generated from two principal sources, automotive and industrial sectors. Used oils from the automotive sector are generated primarily from service stations or the "do-it-yourselfers". Service stations account for the majority of the potentially recoverable used oils from the automotive sector. However, the "do-it-yourselfer" used oil source deserves special attention because it is the most important area where the least percentage of the potentially recoverable oil is collected. The Canadian Association of Re-Refiners (CARR) estimates that 50% or more of household automotive oil changes in Canada are done by "do-it-yourselfers". Cameron and Ross (1979) conducted a survey of 3 000 households in Edmonton and 280 households in a rural Alberta community (the St. Paul area) during 1978. Their findings were that only 21% of the urban "do-it-yourself" (11% of the respondents) returned their oil to service stations, while 55% of the rurally-generated used oil was returned to a centrally located service station. In both survey areas, all the households were aware of the opportunities for returning their used oils.

Until recently, there were no incentives offered to encourage the return of used oils from the "do-it-yourselfers". In addition, there are no permanent government sponsored collection systems in place anywhere in Canada.

A number of voluntary used oil recovery programs have been recently established in Alberta, British Columbia and Ontario. They are primarily based on the Ontario experience, particularly that gained through a joint government/industry sponsored pilot program in Kitchener-Waterloo during 1979 to 1980. Today, there are more than 500 service stations in the Metro Toronto area and more than 300 "oil drop" stations across Alberta which accept used oil (McLaren and Reeve, 1982).

TABLE 15 USED OIL COLLECTORS IN CANADA (updated from Fisher, 1986)

Province	Collector	Estimated Provincial Product Destination
Newfoundland	Delta Oil	85% Burning
	Maritime Oil	15% Road Oiling
		0% Re-refining
Nova Scotia	Maritime Oil	85% Burning
	Inland Oil	15% Road Oiling
	Atlantic Industrial Cleaners	0% Re-refining
New Brunswick	Shrew Oil	85% Burning
	Irving Oil	15% Road Oiling
		0% Re-refining
Quebec	CanAm Oil	20% Burning
	COM-Lub	0% Road Oiling
	Oil Canada*	80% Re-refining
Ontario	DA-Lee Dust Control	10% Burning
	CanAm Oil (Breslube)	15% Road Oiling
	Oil Canada	75% Re-refining
	Chambers Road Oil	
Manitoba	Consolidated Oil	60% Burning
	Oil Canada	5% Road Oiling
		35% Re-refining
Saskatchewan	Gopher Oil	60% Burning
	Nickel Oil	5% Road Oiling
	Magnum Oil	35% Re-refining
	Turbo	
	HUB Oil	
Alberta	Carmoil Trading	35% Burning
	Hub Oil	5% Road Oiling
	Turbo	60% Re-refining
	Dust Oil Control	
	Three-Way Trucking	
British Columbia	Mohawk	2% Burning
	Master Wash	38% Burning
	United Oil	60% Re-refining

* former name: Canadian Oil

In order to facilitate the collection of used oils, most modern gas stations provide a 2 300- to 4 500-litre storage tank. Used oil segregation is often virtually non-existent, and the tanks may end up collecting solvents, grease drippings and other related contaminants generated during regular service station operations. Only in the industrial sector, where larger quantities of certain used oils (such as cutting oils, machinery oils and hydraulic oils) are generated and where economic incentives exist to reprocess such oils, limited segregation of used oils is practiced (Skinner, 1974).

When used oil is collected, it is transported in 2 300- to 9 000-litre capacity tank trucks to storage until it is reprocessed, recycled, reused or disposed of. Most major used oil collectors operating in large cities, voluntarily follow the *Transportation of Dangerous Goods Act* and regulations for the transport of used oils. For example, Turbo of Edmonton has a permit from the Alberta Government for its collection truck fleet, follows the manifest procedure, and displays placards during the transport of used oils.

3.2 Problems and Alternatives

Collection is the first and the most important step, and often the weakest link, in the overall system of used oil management. As concluded in Section 2.2, about one-half (41%) of the total recoverable used oil in Canada is currently collected in Canada. According to a United States estimate, "do-it-yourselfers" dispose of approximately 14% of the total recoverable used oil through random dumping and backyard burning (Franklin Associates Ltd., 1985).

Current used oil collection and storage systems in Canada are simple and non-selective. For large segments of the used oil industry, such as "do-it-yourselfers", small businesses and farms, adequate storage facilities are not available. The oil is simply disposed of by the user in the most convenient way. In general, there is little incentive for users to accumulate, return, or segregate used oils.

In West Germany, a comprehensive system for the collection and utilization of used oils has been developed under the "user-pays-for-disposal" concept (approximately 5¢/litre of virgin lube oil in 1980). It is based on a regional collection network, with free collection of used oils in quantities greater than 200 L by government contracted and subsidized collectors. These used oil collectors, who are often used oil utilizers/disposers themselves, are licensed and their operations and facilities are monitored. They are also required to maintain records of the composition and volume of used oils handled. The West German government has recently agreed with the oil industry, retailers and local governments to voluntarily provide used oil collection facilities for "do-it-yourselfers", either at the place of sale, at service stations, or at municipally maintained locations.

In the United States, used oil is not classified as a hazardous waste. Used oil generators are prohibited from mixing hazardous wastes, such as spent solvents, with used oil. If used oil is mixed with other hazardous wastes then the resulting mixture (regardless of halogen concentration) is regulated as a hazardous waste, and the facility has to comply with hazardous waste generator regulations.

A conceptual illustration of a collection system which could be used to improve the recovery of used oils in Canada is provided in Figure 1. This collection system includes the following components:

- used oil generator includes the 'do-it-yourself' oil changer as well as commercial and industrial operations which do not have in-house capabilities for recycling oil;
- generator oil delivery route applies to small volume generators who do not have on-site storage equipment and therefore must transport used oils to facilities which do;
- local collection centres are establishments (e.g., service stations, automotive retail outlets and dealers, municipal collection depots) which make their used oil storage facilities available to small volume generators;
- local collection routes are followed by used oil collectors and/or processors to collect oils from local collection centres and commercial and industrial operations with in-house storage equipment;
- regional transfer stations are where oils from local collection centres are delivered; they are equipped with underground oil storage vessels of a size sufficient to make long haul transport of oils economically feasible;
- regional collection districts supports each regional transfer station; districts are sized by considering the combined capital and operating costs associated with their collection systems; large districts minimize unit capital costs for transfer stations but increase the operating (i.e., trucking) costs for local collection; the optimum district area would be that with the lowest total capital and operating cost; and
- long haul collection route large highway tankers would be used to transport oils from the regional transfer stations to the recycling or end use location.

Implementation of this system on a large scale would involve dividing provinces or areas into regional collection districts supplying one or more centralized oil users (e.g., re-refinery). Ideally, collection districts would be broad enough to cover entire provinces; however, this may not be feasible in areas with few generators and/or local collection centres. If provincial geography and demographics are such that used oil recoveries (approaching 100%) are not feasible, collection efforts would first be directed at those areas with the highest concentrations of used oil and local collection centres.

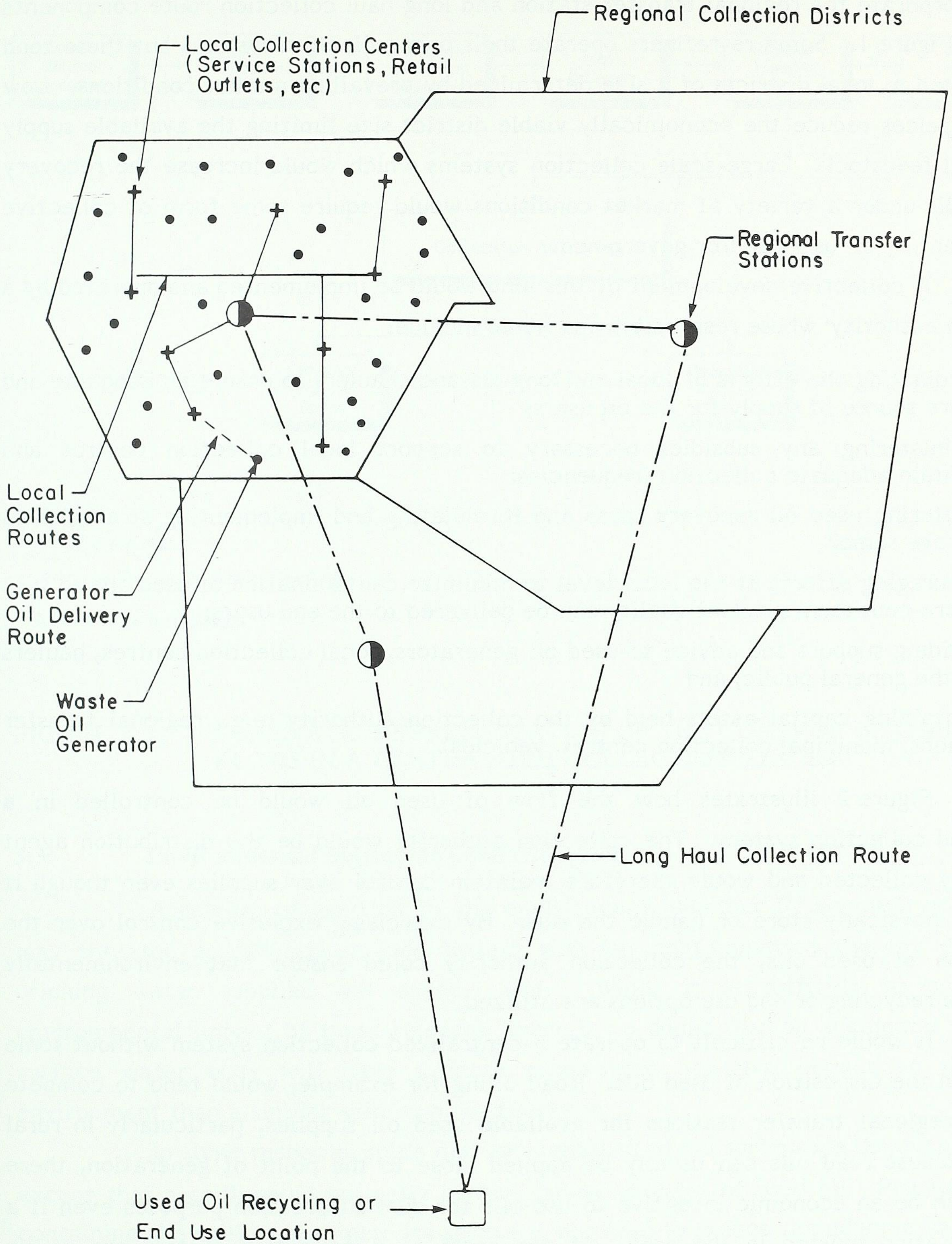

FIGURE 1 CONCEPTUAL ILLUSTRATION OF A USED OIL COLLECTION SYSTEM

At the present time in Canada, there are no large-scale collection systems which incorporate the regional transfer station and long haul collection route components shown in Figure 1. Some re-refiners operate their own collection systems but these tend to be limited to local districts of a size determined by prevailing market conditions. Low world oil prices reduce the economically viable district size limiting the available supply of used oil feedstock. Large-scale collection systems which would increase the recovery of used oils under a variety of market conditions would require some form of collective development by oil users and/or government.

A collective development of this kind would be implemented and operated by a 'collection authority' whose responsibilities would include:

- coordinating the efforts of local and long distance haulers to ensure an adequate and secure source of supply for the oil users;
- administering any subsidies necessary to support local collection centres and maintain adequate collection frequencies;
- monitoring used oil recovery rates and formulating and implementing strategies to improve same;
- encouraging efforts at the local level to minimize contamination of used oils so that a more consistent product quality can be delivered to the end users;
- providing support and advice to used oil generators, local collection centres, haulers and the general public; and
- maintaining capital assets held by the collection authority (e.g., regional transfer stations, municipal collection centres, vehicles).

Figure 2 illustrates how the flow of used oil would be controlled in a centralized collection system. The collection authority would be the distribution agent for all oils collected and would therefore maintain control over supplies even though it would not physically store or handle the oils. By exercising exclusive control over the distribution of used oils, the collection authority could ensure that environmentally acceptable recycling or end use options are utilized.

It would be difficult to operate a centralized collection system without some controls on the disposition of used oils. Road oiling for example, would tend to compete with the regional transfer stations for available used oil supplies, particularly in rural areas. Because road oils can usually be applied close to the point of generation, there could often be an economic incentive to use oils for dust suppression purposes even if a transfer station existed in the area. If the costs of a collection system are to be maintained at reasonable levels, oil volumes directed to it must be maximized so that economies of scale can be realized.

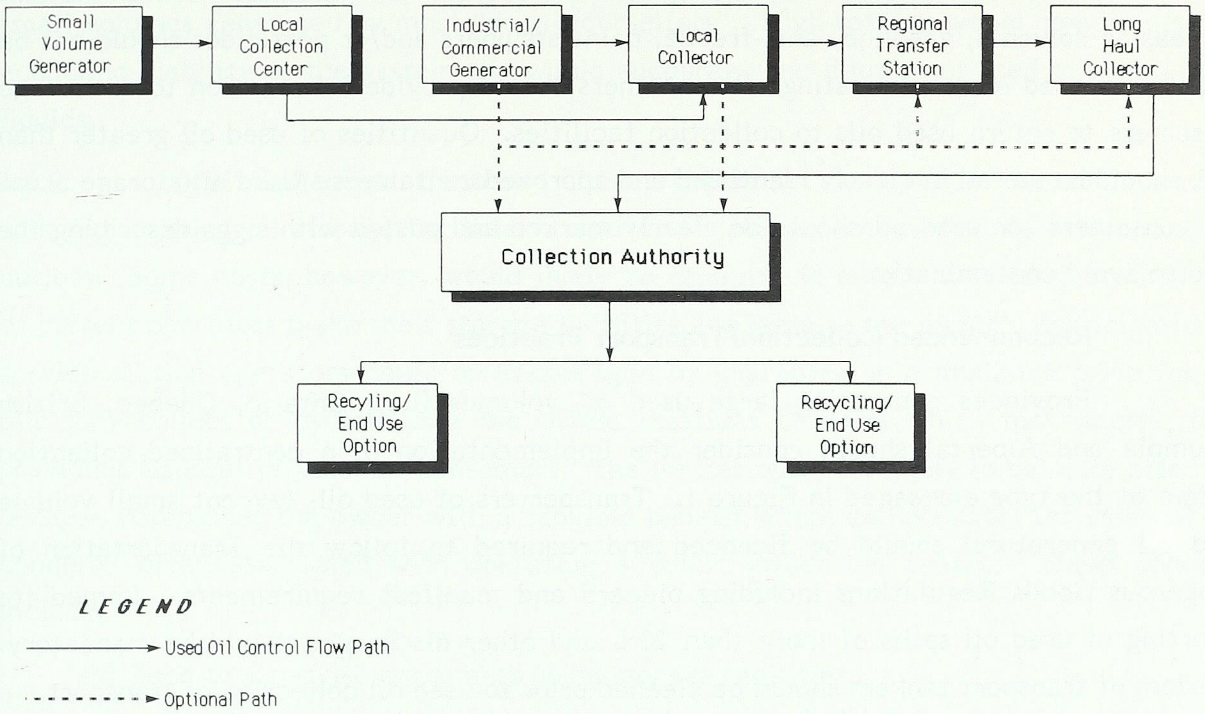

FIGURE 2 SCHEMATIC REPRESENTATION OF THE CONTROL OF USED OIL FLOWS IN A CENTRALIZED COLLECTION SYSTEM

3.3 Environmental Impact of Used Oil Spills

A release of used oil to the environment, whether by accident or otherwise, may threaten ground and surface waters with oil contamination thereby endangering drinking water supplies and aquatic life. While it is difficult to quantify the environmental impact of these releases, there is no doubt that an accidental spill into a surface water body will have a more pronounced negative impact on the aquatic environment than a similar spill on a road surface.

In some respects, spills may be compared to indiscriminate dumping of used oil except that a spill would normally involve larger volumes of used oil. Prompt action in containing the spill to minimize its spread is required to reduce the adverse impact of the oil on the environment. Cleanup action may involve the use of absorbent pads or removal of contaminated soils from the site.

3.4 Recommended Used Oil Handling Procedures

Used oils should be segregated at source to minimize contamination. Degreasing solvents, gasoline, anti-freeze, paint strippers and/or pesticides should not be mixed with used oil. Lubricating oil containers should provide information to encourage consumers to return used oils to collection facilities. Quantities of used oil greater than 20 L should be stored in clearly identified and approved containers. Used oil storage areas and containers for used oil should be clearly marked and posted with signs describing the need to avoid contamination.

3.5 Recommended Collection/Transport Practices

Provinces generating large used oil volumes (i.e., Ontario, Quebec, British Columbia and Alberta) should consider the implementation of a centralized collection system of the type envisaged in Figure 1. Transporters of used oils (except small volume used oil generators) should be licenced and required to follow the Transportation of Dangerous Goods Regulations including placard and manifest requirements. Immediate reporting of used oil spills of more than 20 L and other discharges should be mandatory. Interiors of transport tankers should be cleaned prior to used oil collection or transport.

3.6 Costs

Costs for implementing a centralized collection system similar to that shown in Figure 1 would consist of:

- capital costs for the installation of local and regional collection systems;
- operating subsidies during unfavourable market conditions; and
- administrative costs associated with implementing and enforcing legislation, monitoring and enhancing the system's oil recovery rate and securing environmentally acceptable markets for all used oils collected.

The following sections outline where these costs would be incurred in the development and operation of a used oil collection system.

3.6.1 Used Oil Generators. Administrative costs would be incurred by implementing mechanisms which would compel small volume oil generators to transport their oils to local collection centres. Possible mechanisms include:

- a public education campaign designed to heighten awareness of the environmental risks associated with improper disposal;
- labels on oil containers encouraging consumers to return used oils to appropriate collection facilities; and
- provision of a refund to used oil generators.

The first two approaches would probably be the most feasible. A refund that was in itself sufficient incentive to return used oils would have to be very high given the small volumes generated by most "do-it-yourselfers". High refunds would compromise the economic viability of the system and would encourage the dilution of used oils with other liquids.

3.6.2 Local Collection Centres. Local collection costs could be minimized by utilizing existing oil storage facilities at service stations, automotive dealers and retail outlets. Some costs, however, would likely be required to ensure that adequate numbers of current operators make their storage facilities available to the public. Participation of service station operators could be encouraged by guaranteeing a minimum price for the oils they collect or by stressing the public relations benefits which may accrue from providing disposal services to consumers. The former option is likely to be more effective because it provides the owner with a tangible benefit which compensates for some of the concerns often associated with operating a public collection centre. These concerns include:

- the need to supervise consumers using storage facilities;
- costs associated with cleaning up spills and protecting facilities from vandalism;
- the increased potential for contamination of used oil supplies;
- disposal of used oil containers;
- increased congestion in a working area; and
- reduction in automotive service business by making it easier for consumers to change their own oil.

Retail outlets which sell motor oil should be required to provide publicly available used oil collection facilities. Should legislation be necessary to do this, administrative costs would be incurred for its formulation and enforcement.

Service station owners and retail outlets should also consider implementing procedures to protect themselves against receiving unwanted or contaminated oils. These procedures should include:

- post a sign stating the used oil products, buy brand or generic names, which are accepted for collection;
- erect an information board or provide information regarding disposal options for used oil products which are not acceptable (i.e., names, addresses and phone numbers of local collectors or government agencies involved in special waste collection);

- introduce a receipt system requiring the customer to complete and sign a simple "tick-off" form regarding the nature of the used oil (i.e., crankcase oil, power steering or brake fluid, transmission fluid, and other, "specify"); and
- erect a fence with a locked gate around the oil drop-off facility or use drums with locked caps (as used for automotive gas tanks). Ensure that each customer fills out a receipt before the key for access is released.

All of the recommended procedures serve to protect the local collector against liability problems which may arise from people willingly or inadvertently dropping off hazardous or unwanted used oils.

Small municipalities in rural areas may not have enough service stations to make a regional collection system workable. Capital expenditures would then be required to provide publicly available storage facilities in appropriate areas. There would be a requirement for operating funds to maintain these facilities, discourage vandalism and minimize contamination of oil supplies.

Unattended collection centres should be designed and operated considering the following:

- the site must be accessible but located away from drainage systems and environmentally sensitive areas;
- the area should be posted with signs advising generators to avoid contamination of used oil, the sign should list restricted used oils which are not accepted at the centre (antifreeze, brake and steering fluids, paints, solvents and gasolines);
- secure waste repositories for empty used oil containers should be provided;
- the area around the tank inlet and waste repository should drain to an interceptor (i.e., oil-water separator);
- the centre should be inspected regularly to ensure adequate collection frequencies;
- the centre should be equipped with a telephone and a list of emergency phone numbers to call in case of a spill, vandalism or a full tank; and
- a reasonable level of cleanliness should be maintained to avoid a messy appearance which would discourage small volume generators from using the facilities.

3.6.3 **Local Collection Routes.** Used oils would normally be transported from the local collection centres to the regional transfer stations by independent trucking operators. Operating subsidies may be required to ensure adequate collection frequencies when oil prices are low or where distances are great.

In urban areas which consistently generate large used oil volumes it may be cost effective for the collection authority to maintain a fleet of vehicles. Such a fleet would reduce costs provided oil volumes are sufficient to keep the trucks operating to capacity.

3.6.4 Regional Transfer Stations. Capital expenditures would be required for the construction of transfer stations in each regional collection district. These expenditures would include costs for:

- site acquisition and preparation;
- underground storage tanks;
- liner(s) below and around storage tanks (if required);
- access roads;
- loading/unloading facilities; and
- perimeter fencing.

Operating funds would also be required for the maintenance of transfer stations.

3.6.5 Long Haul Collection Routes. Independent tanker operators would be contracted to transport oils from the regional transfer stations to the centralized end users. These operators would either receive direct payment for their services or a guaranteed minimum price for the oil they deliver.

3.6.6 Miscellaneous Expenses. The recommendation that used oil carriers be required to observe the Transportation of Dangerous Goods Regulations and maintain used oil documentation may increase the rates levied by independent contractors. These increases are unlikely to be prohibitive as most TDG regulations require procedural rather than structural adjustments.

Administrative expenses would be incurred for the operation of the collection authority required to manage the collection system.

3.6.7 Overall Collection System Costs. Table 16 provides a qualitative summary of how costs would be expended in a centralized used oil collection system. Quantitative estimates would have to be developed on a provincial or regional basis and would be sensitive to world oil prices, the number of environmentally appropriate end uses available and the geographic density of used oil generators.

In 1975, Synergy West Ltd. developed a cost estimate for a used oil collection system in Alberta (Synergy West Ltd., 1975). The proposed system was similar conceptually to that shown in Figure 1. The researchers estimated that the system could be operated at an average cost of about 4¢/L (1987 dollars) if it was comprehensive enough to include all of the 34×10^6 L/yr of used oil estimated to be recoverable at that time. While this research is dated and the reported costs therefore open to question, one

TABLE 16 QUALITATIVE SUMMARY OF REQUIRED EXPENDITURES FOR DEVELOPMENT AND OPERATION OF A USED OIL COLLECTION SYSTEM

Component	Expenditures Required		
	Capital Costs	Operating Costs/ Subsidies	Administrative Costs
Used Oil Generators			
- incentives to collect rather than dispose of oils			X
Local Collection Centres			
- incentives to encourage service station operators to give public access to storage facilities		X	
- required retail outlets to provide public collection facilities	X		X
- construct collection centres in small municipalities	X	X	
Local Collection Routes			
- incentives to ensure adequate collection frequencies		X	
Regional Transfer Stations	X	X	
Long Haul Collection Routes		X	
Collection Authority			
- management of collection system			X

of its primary conclusions is still sound; that is, used oil collection systems could be operated in most provinces at reasonable cost if the scope of the operation was sufficiently broad to encompass large oil volumes.

4 USED OIL REPROCESSING AND RE-REFINING

4.1 General

Re-refining and reprocessing are the most satisfactory alternatives for used oil recycling because they either restore the original usefulness of the oil or clean the contaminated oil to a point suitable for subsequent reuse. While re-refining often involves a series of sophisticated processes, reprocessing or reclaiming is essentially a much simpler form of physical/chemical treatment whereby the basic contaminants of used oil are removed. The advantage of reprocessing over conventional re-refining is that additives do not require replacing in order to return the oil to specification. Segregation of used oil stocks is essential, as reprocessing of mixed oils is not possible.

Commonly employed reprocessing methods include settling, dehydration, flashing, filtration, coagulation and centrifugation. Re-refining may include some of these steps followed by or combined with other processes such as chemical treatment, distillation, stripping, clay contacting, solvent extraction, and hydrogenation.

Used oils are classified into two groups in Table 17: re-refinable and non-re-refinable (for reuse/recycling). The inclusion of polynuclear aromatics (PNAs) in the non-re-refinable group, seems debatable since PNAs exist in unused lube oil at trace levels (see Table 10). Used oil contaminated with PCBs, such as those drained from transformers, can be treated for recycle by various proprietary processes (e.g., PCBX by Sunohio). These processes are effective at removing PCBs in used oil with contamination levels to a few thousand ppm.

4.2 Reprocessing Practices

Reprocessing is most often used for industrial oils. There are two major used oil reprocessing companies in Canada: Petroleum Recycling Services Ltd. of Toronto and Chem-Ecol Ltd. of Cobourg, Ontario (Proctor and Redfern et al., 1984). In addition, the railway companies of Canadian Pacific (CP) and Canadian National (CN) reprocess some of their diesel engine lubrication oils by a technology offered by Zimmark Inc. (pers. comm. Skinner, 1987).

Petroleum Recycling Services operates three mobile units with recycling capacities to 2 700 L/h. Basically, treatment includes settling, filtration and vacuum evaporation. The system can be used to treat oil in company-heated settling tanks or can be connected directly to machinery for recycling without equipment shutdown. The process has been commonly applied to the treatment of refrigeration oils.

TABLE 17 CLASSIFICATION OF USED OILS FOR RE-REFINING PURPOSES (from The Canadian Association of Re-refiners, 1987)

Re-refinables (Complete List)	Non-re-refinables (Partial List)
High Viscosity Index (HVI) Oils Only	**Polychlorinated Biphenyls (PCBs) and Polynuclear Aromatics (PNAs)** (unacceptable at any detectable concentration)
All diesel and gasoline crankcase oils	LVI and MVI oils
Transmission oils	Halides
Hydraulic oils (non-synthetic)	Synthetic oils
Gear oils (non-fatty)	Brake Fluids
Transformer oils (if non-PCB)	Fatty oil
Dryer Bearing oils	Asphaltic oils
Compressor oils	Black oils
Turbine oils	Bunker oils
Machine Oils (non-fatty)	Metal working oils containing fatty acids
Grinding Oils (non-fatty)	Form oils
Quenching Oils (non-fatty)	Rolling oils
	Solvents of any type

Chem-Ecol also specializes in custom recycling of industrial oils. The company utilizes the dehydration/clay method at its plant which is designed to process more than 4 000 000 L of used oil per year. By returning the reprocessed or cleaned oil to the industry where the oil was originally used, quality is ensured.

Zimmark's reprocessing technology was developed by British Rail. Chemicals are added to the used oil, and it is cleaned by heating to coagulate and settle the contaminants. After dirt and metal contaminants are removed, the reclaimed oil is blended with oil at a ratio of 1:4 at Canadian National's facilities. Canadian Pacific reprocessed 300 000 L at their Montreal facility during 1987 (pers. comm. Wilson, 1988). Canadian National reprocessed 700 000 L at their facilities (in Edmonton, Winnipeg, Toronto, Montreal and Moncton) during 1987. During 1988, Canadian National is expected to reprocess a total of 1 000 000 L (pers. comm. Wilson, 1988).

Reprocessing technologies produce waste sludges from the filtration, settling and coagulation processes. The disposition of these waste sludges at the previously described facilities is not completely known; however, they are presumably landfilled or incinerated. Canadian National and Canadian Pacific combine their waste sludges with other on-site produced wastes and incinerate the combined wastes in boilers (per. comm. Wilson, 1988).

4.3 Assessment of Re-refining Practices and Alternatives

There are seven re-refiners currently operating in Canada. Table 18 provides the details of these re-refiners including location, plant capacity, current throughput, and respective type of re-refining process. Based on the current total re-refining capacity, it is estimated that as much as 224.5×10^6 L/yr used oil (equivalent to 56% of the total generated) could be re-refined and recycled under favourable market and collection conditions. A new re-refinery (located in Rexdale, Ontario and owned by Corundol Oil and Grease, Inc.) is scheduled to commence full-scale operation during 1988 (pers. comm. Hassan, 1988). The present annual capacity of the facility is 4.5×10^6 L (with facilities for increasing the capacity to at least 13.5×10^6 L/yr). The facility uses the vacuum distillation/clay process.

The Canadian re-refining potential is not presently realized due to unfavourable market conditions (Elliot, 1986). These conditions include:

- the present low market prices for crude oil, which reduce, or possibly eliminate the profitability of collecting and re-refining used oil;
- the Canadian federal sales tax, introduced in 1982, on re-refined oil which is considered a manufactured product;
- the lack of active environmental and financial regulatory controls over competitive used oil dispositions (i.e., burning, road oiling and dumping); and
- the public's misconception that re-refined oil is inferior relative to refined virgin oil.

4.3.1 Re-refining Practices and Alternatives. There are five major commercially proven processes for re-refining used oil:

- acid/clay;
- vacuum distillation/clay polishing;
- vacuum distillation/hydrotreating;
- chemical demetallization/vacuum distillation/hydrotreating; and
- solvent extraction/acid/clay.

The first four technologies are currently used in North America, whereas the solvent extraction/acid/clay has been popular in Europe. As shown in Table 18, three of

TABLE 18 DESCRIPTION OF RE-REFINERS IN CANADA (updated from Fisher, 1986)

Re-refiner	Province	City	Plan Capacity ($x10^6$ L/yr)	Throughput Feed-1986 (10^6 L/yr)	Type of Process
Mohawk	B.C.	North Vancouver	34	20	Vacuum Distillation/ Hydrotreating
Turbo	Alberta	Edmonton	13	10	Acid/Clay
Hub Oil	Alberta	Calgary	9	4.5	Acid/Clay
Magnum[a]	Sask.	Saskatoon	1	0.5	Acid/Clay
Breslube	Ontario	Kitchener	114	33[b]	Vacuum Distillation/Clay or Hydrotreating
Oil Canada[c]	Ontario	Toronto	49	32	Phillips/Shell Hydrotreating
Corundol Oil	Ontario	Rexdale	4.5	NA	Vacuum Distillation/Clay
Total	-	-	224.5	149[d]	-

a summer operation only
b Breslube re-refined 82 x 10^6 L of used oil in 1986 of which 40% (33 x 10^6 L/yr) was from Canada and 60% for the U.S.
c former name: Canadian Oil
d 100 x10^6 L of Canadian throughput feed (see point b)

the seven Canadian re-refiners (Turbo, Hub and Magnum) operate acid/clay processes and three re-refiners (Mohawk, Breslube and Corundol) use vacuum distillation followed by either hydrotreating or clay polishing. A seventh re-refiner, Oil Canada Ltd., employs demetallization/vacuum/distillation/hydrotreating, otherwise known as the Phillips/Shell hydrotreating process.

All five processes use either acid treatment or vacuum distillation, followed by polishing steps using clay contacting or hydrogen addition. Before applying these re-refining processes, used oil may be pre-treated with solvent extraction or chemical treatment (to remove degraded products, metals, additives and other contaminants), in addition to settling and dehydration. A modern re-refinery, using the vacuum distillation technology, typically processes 23 to 46 x 10^6 L/yr of used oil up to a maximum 90 x 10^6 L/yr. An older acid/clay re-refinery is smaller, processing about 5 to 20 x 10^6 L/yr.

Detailed descriptions of re-refining technologies are available in many publications (Rudolph, 1978; Weinstein et al., 1982; Surprenant et al., 1983). A brief description of each process is given in the following sections.

Acid/Clay Process. The acid/clay process is the oldest and most common re-refining process in North America and Europe. It involves the reaction of used oil and sulphuric acid which dissolves and settles metal salts, particles, aromatics, organic acids, polar compounds and dirt. These contaminants form a sludge which settles from the oil and is drawn off for disposal. Clay addition followed by filtration is used to remove any remaining colour.

Vacuum Distillation/Clay Process. To recover the lube oil from used oil, vacuum distillation is implemented, followed by treatment with clay to remove any remaining colour. As in the solvent extraction/acid/clay process, impurities containing distillation bottoms may be blended with fuel oil to form high ash fuel oil. Varying grades of lube oil may be produced through this process allowing a refiner the added flexibility in blending to meet different product specifications.

Vacuum Distillation/Hydrotreating Process. This process is basically the same as the vacuum distillation/clay process except that lube oil stocks are treated with hydrogen rather than clay. This eliminates the need for disposal of the resulting clay sludge. Hydrotreating is used in the refining and re-refining of lube oils to improve and stabilize their colour.

Solvent Demetallization/Vacuum Distillation/Hydrotreating Process. This re-refining technology is basically a modification of the Phillips Re-Refining Oil Process (PROP) developed by Phillips Petroleum. The modification involves a more sophisticated vacuum distillation scheme. In the PROP process, used oil is demetallized by chemical precipitation and then hydrotreated to produce about 90% yields of base oil (compared to 65 to 83% from other technologies). With the addition of an improved distillation system which can separate light and heavy oils, the modified PROP process can produce a great variety of re-refined lube oils.

Solvent Extraction/Acid/Clay Process. This process is similar to the acid/clay process except that propane is used to extract the lube oil stock from degraded products, contaminants and additives. Impurities from the extracted oil may be blended with fuel oil and used as a high ash fuel oil.

4.3.2 Re-refining Products and By-products. All re-refining facilities produce a re-refined lube oil base stock and a distilled light end fuel oil fraction, some of which is used on-site for heating. The by-products which have marginal values include distillation bottoms (used as an asphalt extender or in fuel oil blending) and demetallized filter cake (used as road base material). The remainder of the materials are residues or waste streams such as acid sludge, spent clay, centrifuge sludge and process water directed to treatment and/or disposal.

Lube oil yield and quality differ for various technologies. For example, vacuum distillation processes typically yield about 10% more oil than acid/clay processes. In addition, base stocks produced from the vacuum distillation processes are of better quality. This is because the acid/clay technologies are less capable of completely removing certain contaminants from used oil than the distillation processes (Surprenant et al., 1983).

The average product/by-product distribution (by volume) from used oil re-refining can be summarized as follows (Franklin Associates Ltd., 1985):

- Re-refined lube oil 74%;
- Light end fuel 7%;
- Distillation bottoms 11%; and
- Waste residues 8%.

4.3.3 **By-product Waste Handling.** Major waste by-products or residues generated from re-refining include acid sludge, spent clay, centrifuge sludge and process waste-water.

Acid sludges from acid/clay and solvent extraction/acid/clay processes contain sulphuric acid, lead, degradation products, organometallics, and other metals and additives. The volume of this sludge is normally too small to be economically attractive for acid and metals recovery, so landfilling has been the most common method of disposal. However, this sludge generates environmental concerns due to its high acid and lead content; therefore, landfill disposal is becoming less common. Alternative treatment/disposal measures such as lime neutralization or shipment to special waste disposal facilities are being considered.

Spent clay is generated in all re-refining processes except vacuum distillation/hydrotreating. It normally contains high oil levels plus colour generating organics, and is usually disposed of by landfilling. Centrifuge sludge is generated in distillation processes. This sludge often contains caustic, sodium silicate, lead, oil and other materials and is also generally disposed of in a landfill.

Process wastewaters include water decanted or flashed from the feed oil, boiler blowdown, cooling water blowdown and condensed process stripping steam. It requires oil/water separation and in some cases neutralization, prior to discharge to municipal treatment facilities. If municipal facilities are not available, more sophisticated treatment systems may be necessary.

Table 19 provides a summary of the quantities of the major waste products generated from acid/clay, solvent extraction/acid/clay, vacuum distillation/clay, and vacuum distillation/hydrotreating re-refining processes. These estimates are based on a re-refining capacity of 25 x 10^6 L/yr.

TABLE 19 RE-REFINERY WASTE STREAMS (adapted from Rudolph, 1978)

Waste Type	Acid/Clay	Solvent Extraction/ Acid/Clay	Vacuum Distillation Clay	Vacuum Distillation Hydrotreating
Acid Sludge[a] (L/day)	15 500	3 800	-	-
Spent clay[b] (kg/day)	3 600	1 470	1 170	-
Centrifuge sludge[c] (kg/day)	-	-	1 090	1 090
Process water[d] (L/day)	6 000	6 800	8 900	12 200

Basis: 25 x 10^6 L/yr used oil feed
a acid sludge generated from acid treating
b oily clay removed from filters
c caustic sludge generated in the naphtha-caustic centrifuging of the dehydrated lube oil in the distillation pretreatment step; this naphtha-caustic pretreatment is not always included in the distillation process; nonetheless, it should be noted that some spent caustic is generated in the hydrotreating process from the scrubbing of overhead sulphur dioxide (SO_2) and ammonia (NH_3).
d water generated in the treating sections, not including surface runoff

4.3.4 Fate of Hazardous Constituents. The fate of hazardous constituents generated by re-refining processes was investigated recently through laboratory simulation studies (Surprenant et al., 1983). Three re-refining scenarios of varying complexity were simulated using settled and dehydrated used oils. The three processes were: acid/clay; vacuum distillation/hydrotreating; and solvent treatment/vacuum distillation/hydrotreating. The results of the first two processes only (used in North America) are presented in the following sections.

Acid/Clay Process. Concentrated sulphuric acid is known to be capable of removing most lube additives and other contaminants such as resinous and asphaltic substances and nitrogen and sulphur compounds. Metals, such as lead and barium, in the used oil are partially removed as insoluble sulphate in the acid sludge. Polar and high molecular weight materials which produce colour and odour are selectively adsorbed by the clay during the clay-contacting process.

The analytical results of the acid/clay laboratory simulations are summarized in Table 20. The data have been normalized to show the distribution of constituents resulting from the processing of 1 g of feedstock. The table shows that acid treatment resulted in an average of 70% removal of the metal contaminants. The removal of lead and zinc through acid contact was 70% and 77%, respectively. The data also indicate that clay was not very effective in removing metals.

Although most of the semivolatile organics were removed by the acid/clay process, the concentrations of organics remaining in the finished product were still significant. The acid treatment step appears to have effectively destroyed n-nitrosodiphenylamine (added as a spike) and two phthalates. Benz(a)anthracene also appears to have been effectively removed by the combined treatment of acid and clay.

Vacuum Distillation/Hydrotreating. Experimental simulation was conducted by feeding the dehydrated (or topped) used oil to a thin film evaporation or vaccum distillation apparatus. The intermediate distillate produced was hydrotreated to yield a high quality lubestock.

The analytical results of the simulation are summarized in Table 21. Again, the data for all product and waste streams have been normalized to reflect the distribution of contaminants per one gram of used oil feedstock. Thin film distillation was extremely effective in removing metal contaminants, whereas it left almost all semivolatile organics. Almost all metals of interest were retained in the distillation bottoms. Although hydrotreating is known to be highly efficient in removing sulphur and nitrogen impurities, it appears to be generally ineffective in removing the organic contaminants. Chlorinated compounds such as PCBs and 4,4-Dichlorodiphenylethylene seem to be the exception because they were completely destroyed by the hydrotreating process. The detection of naphthalene at very high levels in the hydrotreated product is attributed to cracking or other reactions in the hydrotreating process.

TABLE 20 DISPOSITION OF CONTAMINANTS IN PROCESS AND WASTE STREAMS DURING LABORATORY SIMULATIONS OF AN ACID/CLAY RE-REFINING PROCESS (from Surprenant et al., 1983)

Parameter	Feedstock	Acid Sludge	Spent Clay	Product
Relative Flow Rate (weight percent)	100	20	15	65
Contaminant Weight (µg/g of feed)				
Metals				
Arsenic	9.7	5.4	<0.2	2.0
Barium	70	41	1.5	12
Cadmium	1.4	1.1	<0.01	<0.1
Chromium	9.5	7.5	<0.01	0.4
Copper	36	41	0.04	0.2
Lead	1 250	880	30	240
Nickel	4.1	4.5	<0.01	<0.2
Zinc	820	630	3.0	9.0
Organics				
Naphthalene	54	90	6.0	3.3
2,4,6-Trichlorophenol	44	14	8.3	3.6
N-Nitrosodiphenylamine	98	ND	ND	ND
Phenanthrene/Anthracene	260	28	10	8.5
Dibutyl phthalate	820	ND	ND	ND
Butylbenzyl phtalate	110	ND	ND	ND
Pyrene	28	ND	0.4	5.0
Benz(a)anthracene	24	ND	0.5	ND
Benzo(a)pyrene	ND	ND	ND	ND
4,4-Dichlorodiphenylethylene (4,4-DDE)	68	2.6	2.6	ND
PCBs	43	3.4	10	2.7

ND = not detected at concentrations above 10 µg/g

The high effectiveness of metal removal from the oil feedstock may be attributed to the experimental conditions where carryover due to physical entrainment or hot-spot volatization was minimized (Surprenant et al., 1983).

4.3.5 Comparison of Re-refining Alternatives. A comprehensive evaluation of existing re-refining alternatives is included in a report prepared for the Ontario Waste Management Advisory Board (Rudolph, 1978). The report presents results of a study on the recovery and reuse of used oils. The evaluation compared acid/clay, solvent extraction/acid/clay, vacuum distillation/clay, and vacuum distillation/hydrotreating processes. The demetallization/vacuum distillation/hydrotreating process was excluded

TABLE 21 DISPOSITION OF CONTAMINANTS IN PROCESS AND WASTE STREAMS DURING LABORATORY SIMULATIONS OF A VACUUM DISTILLATION/HYDROFINISHING RE-REFINING PROCESS (from Suprenant et al., 1983)

Parameter	Feedstock	Distillate	Distillate Residue	Hydrotreated Product
Relative Flow Rate (weight percent)	100	80	20	70
Contaminant Weight (µg/g of feed)				
Metals				
Arsenic	9.7	< 0.6	7.2	< 0.5
Barium	70	< 0.1	67	0.15
Cadmium	1.4	0.1	1.3	< 0.3
Chromium	9.5	< 0.1	7.0	< 0.1
Copper	36	0.6	34	< 0.3
Lead	1 250	0.8	1 150	< 0.5
Nickel	4.1	< 0.1	4.4	< 0.1
Zinc	820	0.3	760	3.4
Organics				
Naphthalene	54	80	ND	550
2,4,6-Trichlorophenol	44	46	ND*	ND*
N-Nitrosodiphenylamine	98	90	ND	55
Phenanthrene/Anthracene	260	180	0.7	275
Dibutyl phthalate	820	16	ND	ND
Butylbenzyl phthalate	110	ND	ND	ND
Pyrene	28	42	0.5	47
Benz(a)anthracene	24	9.6	0.5	6.0
Benzo(a)pyrene	ND	ND	2.6	ND
4,4-Dichlorodiphenylethylene (4,4-DDE)	68	44	1.4	ND
PCBs	43	31	ND	ND

ND = not detected at concentrations above 10 µg/g
ND* = not detected at concentrations above 20 µg/g

from the evaluation because it did not come on stream until 1983. The results of the evaluation are presented in Table 22.

From an environmental perspective, re-refining technologies may be ranked according to the overall effects of their waste streams on the environment. Table 23 provides such a ranking of re-refining waste streams.

Data from Tables 22 and 23 suggest that the acid/clay process is the least environmentally sound of the four re-refining processes. The main reason for this is the large quantity of acid sludge disposal which presents a serious problem. The spent oily

TABLE 22 COMPARISON OF RE-REFINING TECHNOLOGIES (from Rudolph, 1978)

Evaluation Item	Acid/Clay	Solvent Extraction/ Clay	Vacuum Distillation/ Clay	Vacuum Distillation/ Hydrotreating
1. Lube yield[a]	lowest	highest	medium	medium
2. Bright stocks[b]	recovered	recovered	lost	lost
3. Utilities[c]	lowest	highest	low	high
4. Overall energy[d]	highest	high	lowest	medium
5. Hazardous chemicals[e]	sulphuric acid	sulphuric acid	caustic	caustic
Waste Streams (see Table 19)				
6. Acid sludge	most	some	none	none
7. Oily clay	most	some	some	none
8. Caustic sludge or spent caustic	none	none	some	some
9. Process water	lowest	Low	medium	highest

a Lube yield in the acid/clay process is the lowest because of losses to the acid sludge. The two distillation processes do not recover bright stocks; reflected in their medium lube oil recovery. By recovering bright stocks and reducing acid sludge losses (compared to acid/clay), the solvent extraction/clay process shows the highest yield of lube oil.

b Bright stocks are recovered only in the acid/clay and the solvent extraction/clay processes. These two processes would be favoured in the unusual situation where used lubes contained extremely high proportions of bright stocks.

c Utilities. Total external energy (power plus fuel) is lowest for the acid/clay process and highest for the solvent extraction/clay process.

d Overall energy is total external energy (utilities) plus potential energy lost in non-recovered lube oils.

e Hazardous chemicals. In the acid/clay and solvent extraction/clay processes, the operators are exposed to the risk of handling sulphuric acid and the resulting acid sludge. All four processes expose operators to possible chemical burns. The acid/clay process has the largest quantity of acid and sludge to handle, but the extra danger is marginal; careless operation or equipment failure with a small amount of acid can be just as serious as with a large amount.

TABLE 23 RANKING OF RE-REFINING BY-PRODUCT WASTE STREAMS IN TERMS OF ENVIRONMENTAL HAZARD (from Rudolph, 1978)

Waste Type	Degree of Hazard*	Major Hazard Components
Acid sludge	1	sulphuric acid (H_2SO_4) and lead (Pb) content
Caustic sludge	2	sodium hydroxide (NaOH) and lead (Pb) content
Sulphur dioxide (SO_2) emissions	3	known biotic effects
High ash residue	4	lead (Pb) content
Spent clay	5	N/A
Process wastewater	6	N/A
Propane and hydrogen (H_2) emissions	7	N/A

*1 = Most Hazardous
N/A = Not Available

clay is also produced in large quantities, although it is considered less hazardous than the acid sludge.

The solvent extraction/acid/clay process generates acid sludge and spent clay, but in much smaller quantities per unit of re-refined oil produced. As a result, the solvent extraction/acid/clay process may be considered environmentally preferable to the conventional acid/clay process.

4.4 Recommended Practices

Re-refiners should be encouraged to construct new facilities using vacuum distillation processes (vacuum distillation/hydrotreating and vacuum distillation/clay) rather than acid treatment processes (acid/clay and solvent extraction/acid/clay). The former processes generate less wastes than the latter.

4.5 Costs

4.5.1 Re-refining Production Costs. Estimated production costs (excluding used oil feedstock costs) for the acid/clay, vacuum distillation/clay polishing and vacuum distillation/hydrotreating processes are summarized in Table 24. The table shows that both vacuum distillation technologies have lower overall production costs than the older acid/clay technology and also illustrates the economies of scale available at larger production facilities. Data from the literature were insufficient to develop similar estimates for the demetallization/vacuum distillation/hydrotreating process; however, the available information suggests this process can be competitive with the more common vacuum distillation technologies.

4.5.2 Estimated Methodology. The estimates appearing in Table 24 were derived from a variety of information sources (E.R.A. Consulting Economists Inc., 1979; Rudolph, 1978; Synergy West Ltd., 1974; The Canadian Association of Re-refiners, 1987; Weinstein, 1974). To apply these costs, it was first necessary to develop a methodology for presenting all data on an equivalent basis. This methodology made use of three basic factors:

- scale factors;
- escalation factors; and
- currency exchange factors.

Scale factors were required to illustrate the economies of scale associated with re-refining facilities. The following equation was used to adjust data source costs to reflect the various plant capacities noted in Table 24:

$$\text{Cost for any given plant capacity} = \left[\frac{\text{desired plant capacity}}{\text{data source capacity}}\right]^{a} \text{data source cost}$$

where:

a = 0.63 for acid/clay capital costs;
= 0.68 for vacuum distillation capital costs; and
= 0.90 for operating and maintenance costs.

The 'a' factors were derived from cost data (Synergy West Ltd., 1974).

All cost information was updated to first quarter 1987 Canadian dollars using annual inflation rates of 12% to 1982 and 4% thereafter. These figures are consistent with in-house data relating to the price escalation of processing facilities since the early 1970's. Where necessary, American cost data was converted to equivalent Canadian sums using the exchange rate for the year in which the cost data were prepared (the assumption here is that devaluations of the Canadian dollar after this date would be reflected in the Canadian inflation rate).

The unit production costs in Table 24 were calculated using the formula:

$$\text{Unit cost} = \frac{\text{Capital Cost x Fixed Charge Rate + Operation and Maintenance Cost}}{\text{Annual Production}}$$

TABLE 24 ESTIMATED RE-REFINING COSTS (1987 $ Cdn.)

Re-refining Process	Plant Input Capacity (1000's L/yr)	Capital Costs (1000's $)	Operation and Maintenance Costs (1000's $/yr)	Annual Production (1000's L)	Unit Production Costs[a,d] (¢/L)
Acid Clay	5 000	2 100	900	3 600[b]	34
	10 000	3 300	1 700	7 200[b]	30
	20 000	5 100	3 100	14 400[b]	27
	50 000	9 000	7 100	36 000[b]	23
Vacuum Distillation/Clay Polishing	5 000	1 900	700	3 800[c]	26
	10 000	3 000	1 400	7 600[c]	24
	20 000	4 900	2 600	15 200[c]	22
	50 000	9 000	5 800	38 000[c]	19
Vacuum Distillation/ Hydrotreating	5 000	2 300	800	3 800[c]	30
	10 000	3 600	1 500	7 600[c]	27
	20 000	5 800	2 700	15 200[c]	23
	50 000	11 000	6 200	38 000[c]	21

a excluding cost of feedstock
b recovery rate assumed to be 72%
c recovery rate assumed to be 76%
d costs assume plants are fully utilized; unit production costs will be higher if plant is not used to capacity

The fixed charge rate converts the capital costs into an equivalent annual payment and includes the cost of capital, depreciation, taxes, interim replacement charges and insurance. A fixed charge rate of 15% was used for the compilation of Table 24. This figure consists of a capital recovery factor of 11% (based on a nominal capital cost of 10% and a project lifetime of 30 years) and a 4% allowance for taxes, interim replacement costs and insurance.

The values in Table 24 should be interpreted recognizing the limitations of the estimating methodology. The table was developed to characterize differences in costs among the various processes and does not necessarily provide accurate estimates for any particular plant. It should also be noted that the estimates do not reflect costs for disposal of process by-products at hazardous waste treatment/disposal facilities. It appears likely that when these facilities come on line, re-refiners will be required to use them for at least some of their wastes at costs considerably higher than current disposal charges.

4.5.3 Profitability of Re-refining. Tables 25, 26 and 27 provide estimates of the profitability of the various re-refining processes under two different crude oil price scenarios. The figures for feedstock cost and product selling price are approximations developed from literature sources and discussions with Canadian re-refiners. The tables are not intended to provide definitive measures of profitability for any given facility but rather to highlight differences between processes and to illustrate the sensitivity of profit margins to fluctuations in the world price of crude oil.

The tables show that the vacuum distillation technologies are generally more viable than acid/clay and that the profitability of all processes increases with the price of crude oil. This latter phenomenon results from the fact that feedstock costs account for a high proportion of virgin lube oil refining costs. The price of virgin lube oil stocks are therefore more sensitive to crude oil price increases than are re-refined oil supplies. Conversely, as the price of oil drops toward $13.00/barrel, re-refiners have difficulty competing with virgin lube oil refiners.

Tables 25, 26 and 27 show that the potential for small profits or losses in the re-refining industry is relatively high. Re-refiners have traditionally had difficulty maintaining economically viable operations for a variety of reasons, including:

- competition with burners and road oilers for a reliable and secure source of feedstock;
- high feedstock costs generated by demand for alternatives to virgin fuel oils when the price of oil is high;
- depressed product prices resulting from low virgin lube oil refining costs when the price of oil is low; and
- difficulties of overcoming the perception amongst consumers that used oil is inferior to virgin lube oils.

In addition, the incentive to invest in re-refining facilities is constrained (E.R.A. Consulting Economists Inc., 1979) by:

- a low return on investment relative to burning and road oiling;
- relatively high risks resulting from uncertainty of feedstock supplies and the technical difficulties associated with processing and marketing; and
- the relatively high capital costs involved; most burners and road oilers can enter the market with a small investment and do not require a secure feedstock supply to cover high fixed costs.

TABLE 25 PROFITABILITY OF THE ACID/CLAY RE-REFINING PROCESS*

		Crude Oil Price					
		$13/barrel			$40/barrel		
Plant Input Capacity (1000's L/yr)	Unit Production Costs (¢/L)	Feedstock Cost (¢/L)	Product Selling Price (¢/L)	Margin (¢/L)	Feedstock Cost (¢/L)	Product Selling Price (¢/L)	Margin (¢/L)
5 000	34	0	25	-9	20	50	-4
10 000	30	0	25	-5	20	50	0
20 000	27	0	25	-2	20	50	3
50 000	23	0	25	2	20	50	7

* all costs in 1987 $ Cdn

TABLE 26 PROFITABILITY OF THE VACUUM DISTILLATION/CLAY POLISHING RE-REFINING PROCESS*

		Crude Oil Price					
		$13/barrel			$40/barrel		
Plant Input Capacity (1000's L/yr)	Unit Production Costs (¢/L)	Feedstock Cost (¢/L)	Product Selling Price (¢/L)	Margin (¢/L)	Feedstock Cost (¢/L)	Product Selling Price (¢/L)	Margin (¢/L)
5 000	26	0	25	-1	20	50	4
10 000	24	0	25	1	20	50	6
20 000	22	0	25	3	20	50	8
50 000	19	0	25	6	20	50	11

* all costs in 1987 $ Cdn

TABLE 27 PROFITABILITY OF THE VACUUM DISTILLATION/HYDROTREATING RE-REFINING PROCESS*

		Crude Oil Price					
		$13/barrel			$40/barrel		
Plant Input Capacity (1000's L/yr)	Unit Production Costs (¢/L)	Feedstock Cost (¢/L)	Product Selling Price (¢/L)	Margin (¢/L)	Feedstock Cost (¢/L)	Product Selling Price (¢/L)	Margin (¢/L)
5 000	30	0	25	-5	20	50	0
10 000	27	0	25	-2	20	50	3
20 000	23	0	25	2	20	50	7
50 000	21	0	25	4	20	50	9

* all costs in 1987 $ Cdn

5 USED OIL END USES

5.1 Introduction

Used oils have traditionally been directed to a wide variety of end uses. These end use alternatives differ from re-refining in that they generally do not recycle the lubricating value of waste oils and are therefore less attractive from a resource conservation point of view. The end uses of used oil include burning, road oiling and asphalt production in addition to a number of relatively minor end uses. The following sections provide a detailed assessment of the various end use alternatives, discuss the fate of used oil constituents for each, outline recommended end uses and summarize some of the cost implications associated with the recommended practices.

5.2 Assessment of Practices and Alternatives

5.2.1 Burning. Virtually any burner designed for No. 6 fuel oil and most burners designed for No. 4 and No. 5 fuel oils can burn untreated used oil. Some equipment modifications may be required for systems designed for the lighter fuels (PEDCo-Environmental Inc., 1984). Since used oil has approximately the same heating value as virgin fuel oil and is often available at lower cost, the burning of used oil has become popular in many areas. Used oil is currently burned (Franklin Associates Ltd., 1985; Proctor and Redfern Ltd. et al., 1984) in:

- various boiler types and sizes;
- small oil space heaters;
- cement and brick kilns;
- asphalt plants; and
- diesel engines.

The potential benefits of burning used oil as fuel include (Chansky et al., 1974):

- utilization of the oil's heating value;
- reduction in the consumption of non-renewable fossil fuels;
- waste reuse by a method with potentially broad applications in industrialized regions;
- provision of a reuse method with minimal waste by-product disposal requirements; and
- productive waste utilization without the need for the development of new technologies or large capital expenditures.

Impurities in used oil may cause burner performance and safety problems such as nozzle and tip erosion, seal damage, filter and strainer clogging, corrosion of heat transfer surfaces, fuel line freezing, burner flameout and heat rate fluctuations. A number of these problems can be mitigated by pretreating the oil by means of reprocessing technology to remove suspended solids and water (Proctor and Redfern Ltd. et al., 1984).

On the negative side, burning used oil creates significant environmental concerns with respect to the release of heavy metals and toxic organics to the atmosphere. Used oil and residual oils and coal with respect to typical concentrations of potentially harmful metals are compared in Table 28. The extent of environmental concerns associated with used oil burning will depend on (Franklin Associates Ltd., 1985):

- the concentration of hazardous contaminants in the oil;
- burner design;
- emission control equipment;
- stack height;
- meteorological conditions; and
- number of point sources within an area.

Presently, there are no provincial or federal guidelines for permissible stack emission levels of contaminants when burning used oil. Forthcoming source emission regulations for municipal solid waste incinerators (which are presently under development by the Canadian Council of Resource and Environment Ministers (CCREM)) may also be applied to used oil burning (pers. comm., Campbell, 1987). The base emission data from which emission limits will be recommended to CCREM are summarized in Table 29. The first of the three table columns shows the capabilities of best available emission control technology for municipal solid waste incinerators (i.e., lime spray drying followed by fabric filters). The second table column shows emission limits which are in effect for municipal solid waste incinerators in other countries. The third table column for the Canadian emission limits was announced by CCREM (October, 1988) for Municipal Solid Waste Incinerators. These limits have been proposed for hazardous waste incinerators and will likely apply to emissions from used oil burning (pers. comm., Campbell, 1987).

The following sections describe the major used oil burning alternatives, discuss the fate of hazardous compounds and characterize the environmental risks associated with each option.

TABLE 28 COMPARISON OF USED AUTOMOTIVE OIL LUBRICANTS TO VIRGIN FUELS (from Rudolph, 1978; PEDCO-Environmental Inc., 1984; and Franklin Associates Ltd., 1985)

Parameter	100% Used Automotive Oil Lubricants	Virgin Fuels: 100% Residual Oil	Virgin Fuels: 100% Coal
Gravity API @ 16°C	24.0	13.2	-
Viscosity (cm^2/S)	0.99	3.79	-
Pour Point (°C)	37	11	-
Flash Point (°C)	140	99	-
Heating Values (kJ/kg)	38 000	43 000	29 000
BS&W (Vol. %)	11.0	1.0	-
Sulphur (wt %)	0.43	2.15	2.75
Ash (wt %)	1.01	0.25	10.5
Arsenic (ppm)	5	0.5	-
Barium (ppm)	48	3	258
Cadmium (ppm)	3	0.5	-
Calcium (ppm)	1 850	48	7 768
Chromium (ppm)	7	3	24
Copper (ppm)	177	1	64
Iron (ppm)	1 025	120	14 467
Lead (ppm)	240*	3	71
Magnesium (ppm)	559	14	1 362
Phosphorus (ppm)	1 250	-	30
Silver (ppm)	1	0.3	1.7
Tin (ppm)	58	-	225
Zinc (ppm)	480	1	123

* this lead value is chosen from a range of 1983 data reported by Franklin Associates Ltd. (1985); the range is from 0 to 3 700 ppm (median of 150 ppm)

TABLE 29 BASIS FOR SOURCE EMISSION LIMITS FOR MUNICIPAL SOLID WASTE INCINERATORS RECOMMENDED TO CCREM*

Parameter (Chemical Abbreviation)	Capability of Best Best Available Emission Control Technology**	Emission Limits in Other Countries**	Recommended Limits
Conventional Pollutants			
Particulate	9 to 70 mg/m^3	13 to 650 mg/m^3	20 mg/m^3
Carbon Monoxide (CO)		50 to 300 ppm	57 mg/m^3
Acid Gases			
Hydrogen Chloride (HCl)	5 to 91 ppm	20 to 670 ppm	75 mg/m^3 (or 90% removal)
Hydrogen Fluoride (HF)			
Sulphur Dioxide (SO_2)	4 to 209 ppm	22 to 250 ppm	260 mg/m^3
Oxides of Nitrogen (NO_x)	170 to 630 ppm	160 to 300 ppm	400 mg/m^3
Metals			
Cadmium (Cd)	<11.3 mg/Nm^3	0.1 to 0.2 mg/Nm^3	100 µg/m^3
Lead (Pb)	1 to 25 mg/Nm^3	3 to 5.3 mg/Nm^3	50 µg/m^3
Chromium (Cr)	0.6 to 6 mg/Nm^3	0.8 to 5.3 mg/Nm^3	10 µg/m^3
Mercury (Hg)	100 to 610 mg/Nm^3	0.2 to 0.8 mg/Nm^3	200 µg/m^3
Arsenic (As)	0.007 to 0.33 mg/Nm^3	0.8 to 0.9 mg/Nm^3	1 µg/m^3
Organics			
Polychlorinated Dibenzodioxin (PCDD)	0 to 24 ng/Nm^3	Total PCDD & PCDF	0.5 ng/m^3***
Polychlorinated Dibenzofuran (PCDF)	0 to 31 ng/Nm^3		
Polycyclic Aromatic Hydrocarbon (PAH)	15 to 130 ng/Nm^3		5 µg/m^3
Polychlorinated Biphenyls (PCBs)	0 to 9 ng/Nm^3		1 mg/kg PCB Input
Chlorobenzene (CB)	80 to 2900 ng/Nm^3		1 µg/m^3
Chlorophenol (CP)	250 to 8400 ng/Nm^3		1 µg/m^3

* Basis for recommendations (Concord Scientific Corp., 1987) will be existing international limits for conventional pollutants, acid gases and metals as well as the removal capabilities of lime spray drying/fabric filter technology.

** Temperature, pressure and moisture conditions are not specified for the reported data.

*** Toxic equivalency factor new international method.

Nm^3 = normal cubic metre (usually atmospheric pressure and 0°C, 20°C or 25°C)

Oil Space Heaters are small combustion units with capacities less than about 400 000 kJ/h that are used to heat either air or water. These heaters are easily adapted to waste oil use and are often designed specifically for that purpose. The principal users of space heaters are service stations, automobile and truck dealerships and vehicle fleet and farm operators (PEDCo Environmental Inc., 1984).

The two types of heaters most commonly fired with used oil are vapourizing pot burners and low pressure air atomization burners. The vapourizing unit burns heated oil vapour while atomization burners atomize the fuel mechanically before ignition. The two systems differ in that the vapourizing unit accumulates much of the unburned residue in the bottom of the fuel pot, whereas the atomization unit discharges most of the inorganic constituents with the flue gases (Finkelstein, 1983; PEDCo Environmental Inc., 1984).

The emissions of most concern when space heaters are fuelled with used oil are metals, halide acids and organics (solvents and chlorinated organics). Several toxic or carcinogenic metals have been found in the flue gas from air atomization burners and vapourizing pot residues. Lead emissions and residues are the primary concern although concentrations of arsenic, barium, cadmium, chromium and zinc may also be significant. Potentially harmful organics in space heater flue gas and burner pot residues include polycyclic aromatic hydrocarbons (PAHs) and polycyclic organic matter (POMs), (Brinkman, Fennelly and Surprenant, 1984).

Space heaters burn comparatively small volumes of oil and the absolute quantity of contaminants emitted is low relative to other large-scale used oil burners. However, because of low stack heights and flue gas stack exit velocities, little dispersion of flue gas contaminants occurs and ground-level concentrations are relatively high, particularly for atomization burners. The environmental risks associated with heater use then, will be strongly influenced by the number of point sources in a given area (PEDCo-Environmental Inc., 1984).

Boilers. A wide variety of oil-fired boiler types and sizes can be used to burn used oils. The most common boiler types and typical capacity ranges for each are outlined in Figure 3. The following basic usage categories for oil-fired boilers are also summarized in this Figure:

- domestic; includes the generation of heat for space heating, water heating, cooking and other household operations at private households, including farmhouses;
- commercial; includes the generation of heat for space heating, water heating and cooking at non-manufacturing establishments such as apartment and office buildings, motels, restaurants, schools and wholesale and retail businesses;

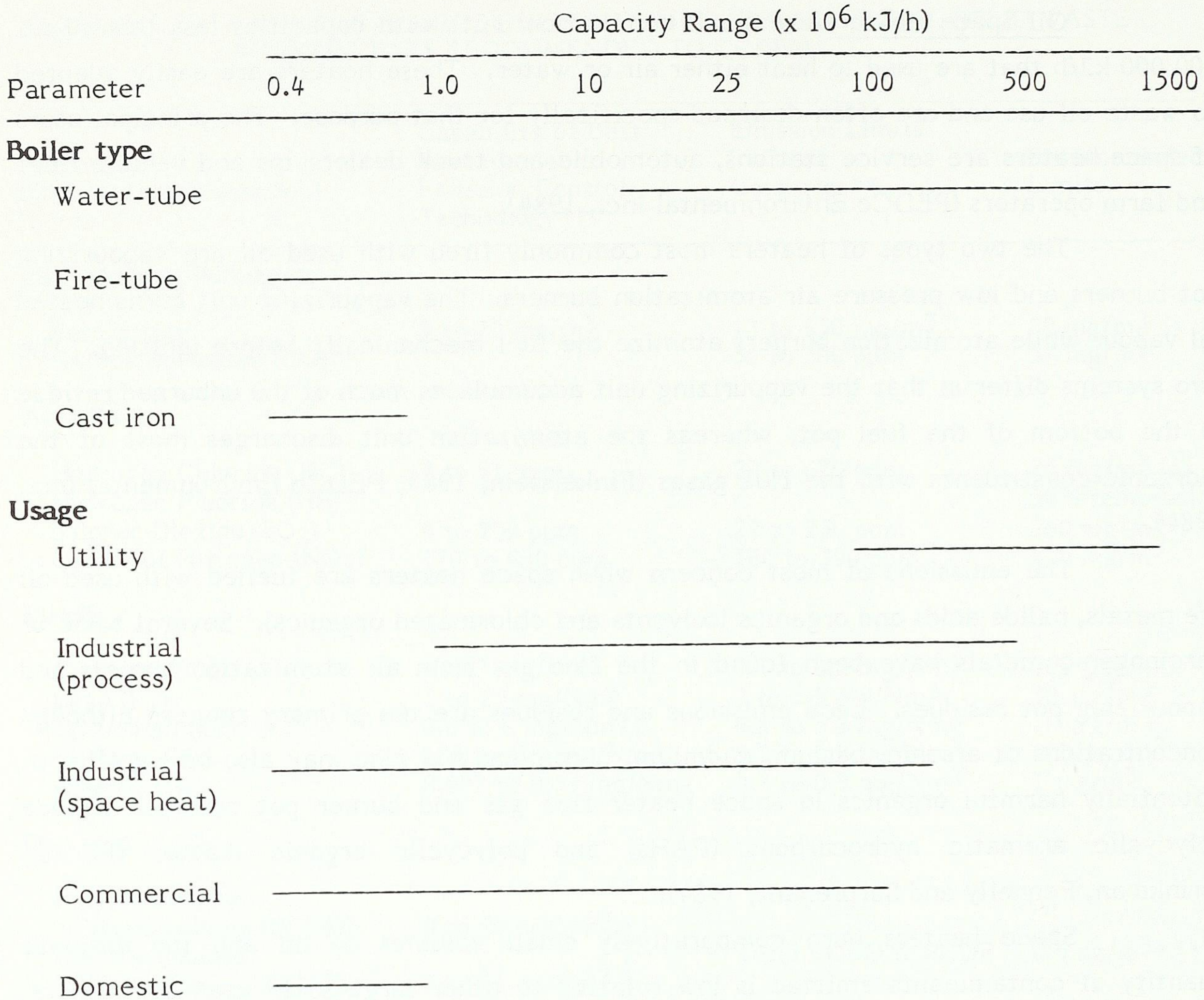

FIGURE 3 SUMMARY OF BOILER CAPACITIES BY TYPE AND USE (PEDCo-Environmental Inc., 1984)

- industrial; includes the generation of steam for space heating and/or process requirements at industrial establishments; and
- utility; includes the generation of steam for the purpose of producing electricity.

Virtually any boiler used for these purposes could burn used oil; however, it is more likely to be burned in equipment designed for residual rather than distillate fuels. In addition, cast-iron and fire-tube boilers are more amenable to used oil fuels than water tube units because they do not have the potential for tube and furnace fouling associated with the latter. Consequently, a large proportion of used oil fuels are consumed in small- to medium-sized cast iron and fire tube boilers.

GCA Corporation in the United States recently completed a study of inorganic and organic emissions in the flue gases of small commercial boilers (400 000 to 15 800 000 kJ/h) fuelled with straight used oil. In general, they found that atmospheric emissions of potentially harmful inorganic compounds, particularly lead and hydrogen chloride, were quantitatively more significant than organic emissions. The reported flue gas concentrations of the more noteworthy heavy metals are summarized in Table 30. A comparison of the values listed in this table and the metal concentration limits listed in Table 29 shows that the limits are exceeded for emissions of lead, chromium, arsenic and, in some cases, the limits are exceeded for emissions of cadmium. Destruction efficiencies for the organic compounds studied were determined to range from 99.4% to 99.96%. The major conclusions of the GCA study were as follows (GCA Corporation, 1984):

- combustion efficiencies greater than 99.9% can be achieved when firing commercial boilers with used oils. It may be impractical, however, to burn undiluted or poorly characterized used oils in smaller boilers (i.e., those with capacities less than about 500 000 kJ/h) due to excessive maintenance requirements;
- destruction efficiencies greater than 99.9% can be achieved for several chlorinated organic contaminants typically present in used oils (e.g., chloroform, trichloroethylene, trichloroethane, perchloroethylene, tri-chlorobenzene, 1-chloronaphthalene and trichlorophenol);
- there is no apparent correlation between boiler size and firing method and destruction efficency for boilers with capacities greater than about 1×10^6 kJ/h;
- inorganic components, principally lead and hydrochloric acid, and particulate matter are the most significant emissions generated by the burning of used automotive oils;
- the presence of detectable quantities of dibenzofurans in boiler flue gases indicated the potential for polychlorinated dibenzofuran and dioxin emissions at parts per billion levels; these compounds were not present in the waste feed and were most likely formed at trace levels during the combustion process; and
- fly ash deposited in the fire tubes of boilers may contain percent levels of lead and parts per billion levels of dibenzofuran and dioxin species. The ash has the potential for being classified as hazardous on this basis.

The results of the GCA study were corroborated by a second investigation conducted by PEDCo-Environmental Inc. (1984). The PEDCo study was designed to quantitatively assess the hazards which might result from the burning of used oils. The investigators determined that emissions of barium, hydrogen chloride and lead could have a significant impact on air quality. They also established that chromium, arsenic, cadmium, dioxins and other organic emissions pose potential cancer risks varying from one in ten thousand to one in one hundred million. The results of PEDCo's risk analysis are summarized in Table 31.

TABLE 30 CONCENTRATIONS OF HEAVY METALS IN FLUE GASES FROM BOILERS FIRED WITH USED OIL (from GCA Corp., 1984)

	Boiler Site Designation ($\mu g/m^3$)						
Parameter	$A^{a,b}$	C^c	D^d	E^e	F^f	G^g	Average
Arsenic	11.2	655	26.1	106	251	286	223
Cadmium	31.2	102	8.3	182	350	81	126
Chromium	62.2	166	112	230	205	263	173
Zinc	5150	33 700	3134	12 100	26 800	27 000	18 000
Lead	9680	72 400	5390	20 300	49 800	51 000	34 800

a waste oil diluted 50:50 with No. 2 oil to improve combustion for test purposes
b 0.53×10^6 kJ/h cast iron boiler with mechanical atomization burners
c 2.5×10^6 kJ/h fire tube boiler with rotary cup burners
d 2.5×10^6 kJ/h fire tube boiler with air atomization burners
e 3.6×10^6 kJ/h fire tube boiler with rotary cup burners
f 4.4×10^6 kJ/h fire tube boiler with air atomization burners
g 13.2×10^6 kJ/h fire tube boiler with air atomization burners

TABLE 31 SUMMARY OF RISK ANALYSIS FOR EMISSIONS GENERATED DURING THE BURNING OF USED OIL (from PEDCO-Environmental Inc., 1984)

Threshold substances* posing a significant health risk:

- Lead
- Hydrogen Chloride
- Barium

Non-threshold substances posing given cancer risk levels:

Risk Level	Non-threshold Substances
10^{-4}	Chromium
10^{-5}	Chromium, Arsenic, Dioxins
10^{-6}	Chromium, Arsenic, Dioxins, Cadmium
10^{-7}	Chromium, Arsenic, Dioxins, Cadmium, Carbon tetrachloride, PCBs, Tetrachloroethylene, 1,1,2-trichloroethane
10^{-8}	Benzene, Trichloroethylene

* those substances for which no adverse health effects are observed below a specified threshold level

Both the GCA and PEDCo studies concentrated on small- and medium-sized boilers with capacities less than about 25 x 10^6 kJ/h. Industrial and utility boilers of larger capacity are generally considered to pose lower environmental risks for the following reasons:

- combustion efficiency; large water tube boilers normally have firebox residence times greater than one second and exit temperatures above 800°C to provide more complete combustion than smaller fire-tube units. In addition, those factors which most strongly influence the quality of combustion (e.g., excess air, fuel homogeneity, firebox heat release rates, on/off cycling) are normally more rigourously controlled in large boilers. For these reasons, small boilers generally discharge relatively large concentrations of incomplete combustion products (i.e., carbon monoxide, hydrocarbons, carbonaceous particles and possibly other chemical species including dioxin) (PEDCo-Environmental Inc., 1984);
- oil quality; industrial and utility boiler operators, as comparatively large used oil consumers, are more likely to implement feed oil monitoring programs to ensure consistent fuel quality. These programs tend to weed out highly contaminated oils which would generate potentially harmful emissions when burned;
- pollution control devices; a relatively good proportion of large boilers are equipped with particulate control devices such as baghouses, electrostatic precipitators and high energy venturi scrubbers. Many of the potentially hazardous used oil emissions are retained by these devices;
- stack heights; large boilers tend to be equipped with relatively tall stacks to increase plume dispersion of contaminants and improve ground-level air quality; and
- location; industrial and utility boilers are not generally located in areas with high population densities. There are also fewer boilers, so that the effects of combined emissions are less likely to be significant.

The environmental risks associated with burning used oil in any size boiler can be reduced through the application of a variety of management strategies. Possible options include (Rudolph, 1978):

- pretreatment of used oil to meet established quality specifications (e.g., settling, centrifugation, vacuum distillation, solvent extraction);
- dilution of used oil contaminants by blending with virgin fuel oils or co-firing with coal;
- installation of flue gas emission control equipment; and/or;
- implementation of a program incorporating various combinations of the above options.

Of these alternatives, pretreatment is most commonly used to improve oil quality. The effectiveness of various treatment techniques for the removal of ash, water, sediments and lead from used oil is summarized in Table 32. The table suggests that while simple physical treatments (e.g., settling, centrifugation) will reduce water and sediment concentrations and their attendant boiler maintenance problems, more elaborate pretreatments (e.g., solvent extraction, vacuum distillation) are necessary to reduce harmful flue gas emissions resulting from trace metal elements and organics in used oil.

TABLE 32 EFFECT OF PHYSICAL TREATMENTS ON WATER, ASH, SEDIMENT, AND LEAD CONCENTRATIONS IN USED OIL

Treatment Process	BS&W (% v/v)	Water (% v/v)	Sediment (% v/v)	Ash (% w/w)	Lead (% w/w)
No Treatment	10	8	5	3	1
Settling pretreatment	1	0	2.5	2.3	0.9
Centrifugation	1.5	1	1.7	1.5	0.75
Solvent extraction	0.3	0	0.3	0.3	0.1
Vacuum distillation	0	0	0	0	0

BS&W - bottom sediment and water

Cement Kilns. Portland cement is produced by reacting limestone, silica, alumina and iron oxide powders in a kiln. The kiln discharge, or clinker, consists of a mixture of calcium silicates, aluminates and ferrites that are ground and blended with calcium sulphate to make Portland cement. Kilns normally burn No. 6 fuel oil, natural gas or coal and can be easily modified to burn used oil treated to remove bottom sediments and water.

Used oil can be burned in cement kilns without many of the negative air quality effects normally associated with burning in small- to medium-sized boilers. By their very nature, kilns exhibit a gas scrubbing action which traps most of the potentially harmful particulate in the clinker. A field trial of used oil burning at a cement kiln in Mississauga showed that 99.97% of the lead in the used oil feed was retained in the process solids. The used oil feedstock contained an average of 0.6% lead. The investigators further determined that the hydraulic and structural properties of the cement would not be compromised by the use of waste oil fuels and that most of the oil contaminants would remain within the insoluble structure of the hydrated compounds in the concrete produced from the cement (Berry and Macdonald, 1975).

Other Burners. Used oil can be burned as a supplemental fuel in pulverized coal-fired boilers. An experimental burn in Minnesota utilizing a 3% oil/97% coal blend demonstrated that all but 0.17% of the incoming lead was absorbed on the fly ash collected by the station's electrostatic precipitators (Pilsworth, 1985). The potential retention of other used oil contaminants in fly ash has not been widely investigated. While it appears that co-firing of used oil and coal may not generate any preclusive air quality effects, the resulting increase in fly ash toxicity would be a concern for many boiler operators.

The burning of used oil in asphalt plants is not uncommon in some areas. The risks associated with this practice would be similar to those for small oil heaters or boilers with no pollution control equipment and low stack heights. Asphalt plants are often situated in sparsely populated areas and are frequently relocated as the market for asphalt moves. These factors mitigate to some degree, the negative environmental effects of burning used oil in asphalt plants.

5.2.2 **Road Oiling.** Used oil has been applied to gravel roads in Canada as a dust suppressant for many years. It has been used most commonly in rural areas with a high proportion of unpaved roads and located some distance from other used oil markets (e.g., burning and re-refining). There have been concerns for some time that the harmful constituents of used oil may impair the health of oil applicators, road users and nearby residents and that they may contaminate soils and local water resources. A number of studies on the environmental effects of road oiling have shown that the ultimate fate of used oil contaminants is determined by a variety of factors including oil properties and soil, meteorologic and traffic conditions.

An early U.S. EPA study (Freestone, 1972) suggested that only about one percent of the oil applied actually remains in the road surface or subgrade. It was determined that 7 to 18% of the oil is lost through evaporation while an additional 10 to 20% is removed by runoff. It was suggested that the remaining portion of applied oil was transported from the road surface through biodegradation and by vehicular re-entrainment of oil-coated particles. The investigators determined that the road surface exhibited elevated lead concentrations and concluded this would be an environmental risk in areas where roadside crops are produced for human consumption.

In 1976, the Petroleum Association for Conservation of the Canadian Environment (PACE) commissioned a study which critically evaluated the U.S. EPA study (Bell, 1976). Some of the major conclusions of the critique are:

- a high oil runoff rate could be expected given the dense and highly impermeable clay road surface used in the U.S. EPA study;
- road surface lead concentrations, while elevated above background, were still below the average for urban soils in Ontario; and
- the U.S. EPA findings applied only to the road section and used oil evaluated and could not be used to develop general conclusions on the environmental effects of road oiling.

A California study evaluated the fate of heavy metals and polynuclear aromatics (PNAs) in used oil applied to unpaved road surfaces (Stephens et al., 1981). The study showed that volatilization, vehicle adhesion and biodegradation accounted for 25 to 30% of oil leaving the roadway while the remainder was removed by runoff and wind entrainment of dust particles. The investigators observed minimal penetration of contaminants below the road surface and determined that only a small portion of the PNAs in the used oil is lost through solubility of these compounds in water.

The United States Department of Energy conducted a study designed to more definitively characterize the fate of road oil contaminants and the environmental impact of road oiling (Surprenant et al., 1983). The results showed that 12% of the applied oil was lost through evaporation and another 3 to 5% was lost by runoff. This runoff loss was considerably lower than that reported in the 1972 U.S. EPA study and the investigators suggested this reduction probably resulted from differences in soil density and road surface preparation. It was determined that virtually all of the oil left in the soil was retained within the upper centimetre of the road surface. Oil concentrations at the surface were 35 000 ppm, while at a depth of one centimetre concentrations dropped to 1 000 ppm. Oil content was indistinguishable from background levels at lower depths. The ultimate distribution of used oil applied to the road surface is summarized in Table 33.

Analyses of runoff samples from the U.S. Department of Energy study showed that most of the used oil constituents in the runoff were associated with soil entrained and carried from the road surface. The water soluble component of road oil was determined to be very small. The concentrations of inorganic and organic road oil constituents in the runoff are summarized in Tables 34 and 35. The only constituent of obvious concern was phenol whose concentration appeared to be above the recommended environmental goals (approximately 5 μg/L). However, the researchers noted that interpretation of this data was difficult because the time variation of contaminant concentrations was not established and because of the possible influence of external

TABLE 33 DISPOSITION OF OIL FOLLOWING APPLICATION TO TEST ROADBED SURFACES (from Surprenant et al., 1983)

Fate of Used Oil	Percent of Total Oil Applied: Roadbed Soil	Percent of Total Oil Applied: Roadbed Soil with 5% Bentonite
Evaporation	>12	>12
Rainfall Runoff		
- insoluble oil constituents	2.7	3.5
- soluble oil constituents	0.03	0.04
Rainfall Penetration into Roadbed		
- insoluble oil constituents	Negligible	Negligible
- soluble oil constituents	0.006	0.001
Remaining in Soil*	~85	~84

* the bulk of the material remaining in the road surface is eventually lost through adhesion to vehicles, biodegradation, and wind entrainment of dust particles

factors such as rainfall pH and sodium concentration, soil leachates and windblown contaminants and dustfall.

The U.S. Department of Energy investigators concluded that undesirable effects could result from the use of highly contaminated road oils, although their results suggested the environmental effect of road oiling is not overly severe. They recommended that additional work be undertaken to more fully characterize potential effects under worst case conditions.

5.2.3 **Asphalt Production.** Used oils have been used as cutting stocks and extenders in the manufacture of asphalt. Since used oil constituents are essentially insoluble in water, potential contaminants are coated with viscous asphaltic materials and incorporated into the final product. Leaching of significant contaminant concentrations from finished asphalt roads and roofs is considered unlikely (Weinstein, 1974).

5.2.4 **Miscellaneous End Uses.** Used oil is sometimes directed to a variety of relatively minor end uses, including (Franklin Associates Ltd., 1985; King, 1980; Weinstein, 1974):

- flotation oil (this use is common in the phosphate industry in some regions of the Southern United States);
- concrete form oil;

TABLE 34 ELEMENTAL METAL TRANSFER FROM OILED ROADBED TO RAINFALL RUNOFF (from Surprenant et al., 1983)

Metal	Metal Concentration in Oil as Applied (µg/g)	Weight of Metal Applied (µg)	Metal Concentration in Runoff* (µg/g)	Weight of Metal in Runoff (µg)	Weight Percent Applied Metal Found in Runoff
Aluminum	31	16 700	1.0	25 000	149
Antimony	0.6	320	<0.01	-**	-
Arsenic	8.1	4 370	<0.03	-	-
Barium	61	32 900	0.005	125	0.4
Beryllium	< 0.1	< 55	<0.0012	-	-
Boron	6.2	3 350	<0.004	-	-
Cadmium	1.3	700	0.001	25	4
Calcium	990	535 000	0.6	15 000	3
Chromium	7.7	4 160	<0.003	-	-
Cobalt	0.8	430	<0.003	-	-
Copper	34	18 400	<0.002	-	-
Iron	214	116 000	0.5	12 500	10
Lead	1 090	589 000	<0.02	-	-
Magnesium	212	115 000	0.35	8 750	8
Manganese	14	7 600	0.02	500	7
Molybdenum	3.2	1 730	<0.002	-	-
Nickel	3.7	2 000	<0.005	-	-
Selenium	< 1	< 550	<0.02	-	-
Silicon	40	21 600	0.6	15 000	70
Silver	< 0.1	< 55	<0.001	-	-
Sodium	257	139 000	3.8	95 000	68
Strontium	1.9	1 030	0.005	175	12
Thallium	< 1	< 550	<0.04	-	-
Tin	16	8 640	<0.03	-	-
Titanium	7.8	4 200	0.002	50	1
Vanadium	4.1	2 210	0.005	-	-
Zinc	740	400 000	0.16	4 000	1

* blank corrected for runoff from unoiled surface

** - = the found concentration is less than the detection limit of the analytical method

- secondary lubricant (e.g., chain oil in the logging industry);
- pesticide carrier;
- weed killer;
- livestock pest control oil;
- all-purpose cleaner; and
- vehicle undercoating.

The environmental effects associated with these end uses vary from one application to another. The nature and extent of concerns for any given application will

TABLE 35 ORGANIC COMPOUND TRANSFER FROM OILED ROADBED TO RAINFALL RUNOFF (from Surprenant et al., 1983)

Organic Compound*	Organic Concentration in Oil as Applied (μg/g)	Weight of Organic Applied (μg/g)	Organic Concentration in Runoff (μg/g)	Weight of Organic in Runoff (μg)	Weight Percent of Applied Organic Found in Runoff
Phenol	11	5 870	0.6	15 000	>100
Chlorophenol	40	21 400	0.2	5 000	23
2,4,6-trichlorophenol	40	21 400	<0.01	-**	-
Nitrobenzene	30	16 000	0.02	500	3
N-nitrosodiphenyl-amine	116	62 000	<0.01	-	-
Naphthalene	440	235 000	<0.01	-	-
Phenanthrene/ anthracene	150	80 100	<0.01	-	-
Pyrene	60	32 000	<0.01	-	-
Benzo(a)pyrene	10	5 300	<0.01	-	-
Dibutylphthalate	60	32 000	0.02	500	2
Pesticide: 4,4-DDE	94	50 200	<0.01	-	-
PCBs (Aroclor 1260)	34	18 000	<0.01	-	-

* volatile compounds not detected

** - = the found concentration is less than the detection limit of the analytical method

depend on the volume of oil used, the operational practices of the companies or individuals involved and the manner in which the oils are ultimately discharged to the environment.

5.3 Current Practice in Canada

5.3.1 Burning

Current Situation. Proctor and Redfern Ltd. et al. (1984) estimated that approximately 2% of the total quantity of used oil generated in Canada is burned in cement kilns and 11% is burned in other facilities. More detailed breakdowns showing quantities directed to oil space heaters, boilers and other burners are not available in the Canadian literature.

Regionally, there appears to be a considerable variation in the fuel use of used oil across Canada. Those areas which have traditionally been large users of fuel oil for heat and steam generation purposes burn more used oil than those regions which rely mainly on natural gas and coal. In the Maritime provinces, between 5% and 75% of the generated used oil is burned as fuel (see Table 7). In Alberta and Saskatchewan virtually no used oil is burned because most existing heaters and boilers use natural gas or coal and cannot be modified to burn used oils as readily as oil-fired equipment.

Legislation. Ontario, Quebec and Manitoba are the only Canadian jurisdictions which specifically regulate used oil burning. In Ontario, a certificate of approval to burn used oil is required under the "Guidelines to be Used in the Assessment of Application for Approval of Vapourizing Type Burner Fired with Used Oils." The certificate specifies operating constraints and site specific requirements for oil quality, burner location and storage facilities. All industrial burners are restricted to using waste oil from diesel engines, hydraulic oils or transmission oils with minimum heating values of 18 000 kJ/kg and ash contents less than 7%. In addition, the Ministry of Environment does not approve the use of waste oil in residential space heaters and presently discourages its use in oil heaters at vehicle sales/service establishments (Ministry of the Environment, 1986).

The Province of Quebec requires that industries and greenhouses burning used oil comply with specified standards for oil quality (see Table 2). Burners must receive prior authorization from the province and their flue gas emissions must not compromise ambient air quality standards (ministère de l'environnement du Québec, 1985).

The burning of used oils as auxilliary fuel in Manitoba is regulated through the licensing of oil burners under the provisions of the Clean Environment Act.

In the United States, the Environmental Protection Agency (U.S. EPA) promulgates used oil quality standards for burners. Used oils defined as 'off-specification' fuels according to the criteria summarized in Table 36 can only be burned in industrial boilers. There are no U.S. EPA controls on the sale or use of 'on-specification' used oil fuels (Males, 1987).

TABLE 36 UNITED STATES ENVIRONMENTAL PROTECTION AGENCY CRITERIA THAT DEFINE OFF-SPECIFICATION USED OIL FUEL (Males, 1987)

Compound or Characteristic	Specification
Arsenic	> 5 ppm
Cadmium	> 2 ppm
Chromium	> 10 ppm
Lead	> 100 ppm
Halogens (total)	> 4 000 ppm
Flashpoint	< 38°C

In summary, present legislation is primarily directed towards regulating the burning of used oil by means of acceptable used oil compositional specifications. This approach is not sufficient nor totally appropriate to regulate contaminant emissions from used oil burning. A more appropriate approach is to issue stack emission guidelines for permissible emission levels of contaminants from the combustion of used oils. Table 29 presents an example of such a regulatory approach for municipal solid waste incinerators. A similar approach should be taken to regulate used oil burning, i.e., the capabilities and costs of present available combustion and flue gas treatment technologies should be reviewed for various sized facilities in Canada with the objective of setting affordable and achievable emission guidelines for used oil burning which minimizes emission of hazardous metals and organics.

5.3.2 Road Oiling.

Current Situation. Table 37 provides rough estimates of the percentage of used oil generated that is used for dust suppression purposes in each province. While road oiling is still common in some jurisdictions, its popularity has declined in recent years because of reductions in the proportion of unpaved roadways, competition from other used oil end uses (e.g., re-refining), availability of alternative dust suppression substitutes (e.g., calcium chloride and surfactants) and preclusive environmental regulations. Provincial highways departments generally do not use waste oils and discourage private contractors from doing so. It is likely that most used oil dust suppressants are applied by small municipalities and individuals in rural areas (Proctor and Redfern Ltd. et al., 1984).

Legislation. Quebec is the only province which specifically bans the application of used oils for road dust suppression purposes. Other provinces and the Territories discourage, but do not prohibit, road oiling.

There are generally very few restrictions on the quality of used oils applied to gravel roads. The only limitation which appears to have acquired significant recognition is the Chlorobiphenyl Regulation Number 3 under the federal *Environmental Contaminants Act*. This regulation limits the concentration of PCBs in road oils to 5 ppm (Industrial Programs Branch, 1986).

5.3.3 Asphalt Production. Despite the apparent environmental benefits of using waste oils in asphalt production, this reuse option is not widely utilized. This lack of acceptance may be related to:

- the need for a reliable source of supply; secure supplies may be difficult to establish for many asphalt plants, particularly temporary installations;

TABLE 37 ROAD OILING PRACTICES IN CANADA (from Proctor and Redfern Ltd. et al., 1984)

Jurisdiction	Percentage of Waste Oil Generated Directed to Road Oiling*
British Columbia	19
Alberta	8
Saskatchewan	28
Manitoba	NA
Ontario	18
Quebec	5
New Brunswick	8
Nova Scotia	NA
Prince Edward Island	22
Newfoundland	4
Northwest Territories and Yukon	NA
Canada	15

* does not include unreported volumes of waste oil used for dust suppression purposes
NA = not available

- the difficulties of accommodating various used oil qualities; and
- the lack of an economic incentive sufficient to justify the additional effort required to use waste oils.

5.3.4 Miscellaneous End Uses. The extent to which used oil is directed to the minor end uses outlined previously has not been documented in the literature. Most published information does not describe these uses extensively and the volumes used are not inventoried.

5.4 Recommended Practices

Of the various alternative end uses described in this section, controlled burning is the only option which should be considered as part of an overall used oil management strategy. The option of road oiling involves unknown environmental risks as evidenced by the present ban on road oiling in Quebec and the discouragement from using this practice by all provincial and territorial authorities. A decision on whether or not to ban road oiling in a given jurisdiction should not be made in isolation, but rather as part of the formulation of a general used oil management plan. The considerations which should enter into this decision are described later. For example, uncontrolled burning or road oiling may be the only alternatives to landfilling or indiscriminate dumping in rural areas and northern regions where the practices of re-refining and controlled burning are not available.

It is possible that some of the minor used oil end uses described previously (e.g., raw material in asphalt production) could be implemented with little or no environmental risk. However, the data currently available do not provide a sufficient basis for recommending any of these minor end uses.

5.4.1 Recommended Burning Practices. The following controlled burning practices are appropriate for used oils. The alternatives are listed in the order in which they should be considered.

1. Burning in cement kilns.
2. Burning in industrial and utility boilers equipped with flue gas pollution control equipment.
3. Burning in boilers not equipped with flue gas pollution control equipment only when used oil fuels meet specified standards for maximum contaminant levels and minimum heating valves.

The burning of used oil in small residential and commercial space heaters (vapourizing pot burners and atomization burners) should be discouraged. The discouragement may not be practical in remote communities and sparsely populated areas. Local authorities in these areas should identify local burners which have the best available design and technology for contaminant destruction and control and which are located in the correct environmental setting (tall chimney and relatively remote and downwind from populated areas). Generators should be encouraged to direct their used oil to these identified local burners, i.e., a local collection system would have to be facilitated. Regulators should also seek to ensure that contaminated solid residuals generated during used oil burning are disposed of in an environmentally acceptable manner.

5.4.2 Barriers to Implementation of Recommended Practices. The two most attractive burning options from an environmental perspective (i.e., fuels for cement kilns and utility boilers) have not been widely applied despite the existence of a number of suitable burners across Canada. While the exact reasons for this vary from region to region, a number of general explanations can be put forward:

- kilns and large boilers require stable, long-term fuel supplies of a consistent quality; additional costs may be necessary to ensure that used oil fuels satisfy these requirements;

- large volume fuel consumers, kiln and utility boiler operators can secure competitively priced virgin fuels under long-term supply contracts;
- large-scale burners are greatly outnumbered by small commercial and institutional burners which are relatively accessible to used oil suppliers;
- in the case of cement kilns, the operator may feel there is a risk that customers may perceive his product to be substandard even if there is no basis for that perception; and
- large burners may be located in the same used oil market as re-refiners. Re-refiners are dependent on an adequate oil supply for their very existence and are likely to be more aggressive in securing a large portion of the available supply to meet their needs.

In the case of large boilers operated by electric utilities some additional factors may come into play (Henz, 1987):

- public utilities are highly visible entities and may be reluctant to become involved in the handling and disposal of what may be perceived as a hazardous waste;
- many generating stations are situated near large bodies of water which may be at risk in the event of a spill; and
- there is little economic incentive to assume the above risks since the utility can pass fuel costs through to the ratepayer.

Many of these barriers could be reduced through implementation of government and/or industry sponsored used oil collection systems similar to those previously described (Section 3.2). These systems would encourage the environmentally acceptable burning by providing a stable used oil supply of certifiable quality.

5.5 Costs

5.5.1 Used Oil Burning Costs. The costs associated with burning used oil in boilers and kilns are related to the provision of:

- receiving and blending equipment;
- storage and containment facilities;
- treatment systems; and
- oil feed systems.

The size and complexity of these systems will vary with the amount of used oil consumed. Small commercial and institutional burners for example may have few, if any, facilities dedicated exclusively to used oils. The oil is simply added to virgin fuel supplies and burned. Kilns and large utility boilers may utilize all of these systems in one form or another. Receiving facilities may incorporate analytical capabilities to ensure the oils burned will not cause serviceability problems or compromise environmental standards.

Treatment systems (normally physical separation equipment incorporated into storage facilities) may be used to provide a more consistant oil quality.

Estimates for the unit costs of burning used oils in both small and large facilities are summarized in Table 38. Small burners are assumed to be commercial or institutional boilers with only rudimentary facilities for the handling and processing of used oils. Dedicated storage tanks and delivery systems would be installed to control the proportions of used oil consumed, but facilities for oil characterization and treatment would not be provided. Large burners are kilns and utility boilers equipped with used oil characterization, handling, treatment (physical separation), storage and delivery systems designed and operated to minimize the operational and environmental risks associated with the consumption of used oils. The estimates in Table 38 do not include costs for flue gas pollution control equipment. It is unlikely that facilities complying with air quality standards using virgin fuels would install this equipment simply to burn used oils.

The estimates listed in Table 38 were derived from base costs reported by Henz (1987) using the estimating methodology outlined previously. Costs for the various

TABLE 38 ESTIMATED COSTS FOR USED OIL BURNING FACILITIES (1987 $, Cdn.)

Used Oil Capacity (1000's L/yr)	Capital Costs (1000's $)	Operation and Maintenance Cost (1000's $/yr)	Used Oil Burning Cost (¢/L)
Small Burners*			
500	45	15	4.4
1 000	70	20	3.1
2 000	110	25	2.1
5 000	190	30	1.2
Large Burners**			
7 000	900	230	5.2
10 000	950	240	3.8
20 000	1 100	260	2.1
50 000	1 300	290	0.95

* commercial, institutional and small industrial burners with rudimentary facilities for the handling and processing of used oils

** kilns and medium to large industrial and utility boilers equipped with specialized used oil storage, containment and delivery systems and on-site facilities for the characterization of used oils facility sizes were calculated using the economy of scale equation with the following 'a' factors:

$a = 0.64$ for small burner capital costs;
$a = 0.28$ for small burner operating and maintenance costs;
$a = 0.17$ for large burner capital costs; and
$a = 0.14$ for large burner operating and maintenance costs;

Unit costs were determined by dividing the sum of annualized capital costs (i.e., capital costs multiplied by a fixed charge rate of 15%) and operating and maintenance expenses by the burner's used oil capacity (note: the calculation assumes that the burner's annual oil capacity is fully utilized).

5.5.2 Economic Incentive for Burning Used Oils. Tables 39 and 40 illustrate the potential savings and costs associated with burning used oil in facilities designed to use No. 6 residual fuel oil. The tables show that for both large and small facilities, the potential benefits of used oil burning increase with oil consumption and the world price of crude oil. This is because economies of scale reduce the unit cost of burning equipment and because higher crude oil prices produce a spread between used oil and virgin fuel prices great enough to exceed the incremental costs of used oil burning.

As noted earlier, the small burners in Table 39 are assumed to have some on-site facilities dedicated solely to the storage and delivery of used oil fuels. Small burners which have no such facilities and simply add used oils to their virgin fuel supplies will have higher net savings than those reported in Table 39. For these facilities, used oil burning will always produce a savings in fuel costs regardless of oil consumption and world oil prices as long as used oil can be obtained at prices below those for virgin fuels. It should be noted, however, that these are also the burners which generate the most severe environmental effects when burning used oils.

Tables 39 and 40 demonstrate why used oil burning has been popular in many areas, particularly for small burners when the price of virgin oil is high. For a modest capital and annual investment, burner operators can realize significant savings in fuel costs. This high economic return (relative to re-refining for example) comes with little risk and generally few technical difficulties.

TABLE 39 ESTIMATED NET SAVINGS/COSTS FOR SMALL BURNERS USING USED OIL INSTEAD OF NO. 6 RESIDUAL FUEL OIL (1987 $ Cdn.)

		13 $/barrel Crude Oil Price					
		14 $/barrel			40 $/barrel		
Annual Used Oil Consumption (1000's L)	Used Oil Burning Cost (¢/L)	Used Oil Cost* (¢/L)	Fuel Savings** (¢/L)	Net Savings/ (Cost) (¢/L)	Used Oil Cost* (¢/L)	Fuel Savings** (¢/L)	Net Savings/ (Cost) (¢/L)
500	4.4	8.0	10	(2.4)	20	25	0.6
1 000	3.1	8.0	10	(1.1)	20	25	1.9
2 000	2.1	8.0	10	(0.1)	20	25	2.9
5 000	1.2	8.0	10	(0.8)	20	25	3.8

* assumed to be 80% of the cost of No. 6 residual fuel oil
** approximate cost of No. 6 residual fuel oil (Oil and Gas Journal, 1985; 1986)

TABLE 40 ESTIMATED NET SAVINGS/COSTS FOR LARGE BURNERS USING USED OIL INSTEAD OF NO. 6 RESIDUAL FUEL OIL (1987 $ Cdn.)

		Crude Oil Price					
		13 $/barrel			40 $/barrel		
Annual Used Oil Consumption (1000's L)	Used Oil Burning Cost (¢/L)	Used Oil Cost* (¢/L)	Fuel Savings** (¢/L)	Net Savings/ (Cost) (¢/L)	Used Oil Cost* (¢/L)	Fuel Savings** (¢/L)	Net Savings/ (Cost) (¢/L)
7 000	5.2	8.0	10	(3.2)	20	25	(0.2)
10 000	3.8	8.0	10	(1.8)	20	25	1.2
20 000	2.1	8.0	10	(0.1)	20	25	2.9
50 000	0.95	8.0	10	(1.1)	20	25	4.1

* assumed to be 80% of the cost of No. 6 residual fuel oil
** approximate cost of No. 6 residual fuel oil (Oil and Gas Journal, 1985; 1986)

6 USED OIL DISPOSAL

6.1 Introduction

Used oil disposal involves the use of facilities or repositories which do not utilize the oil's lubricating and/or heating value. Disposal has traditionally been popular for oils generated some distance from reuse markets, among individuals who change their own automotive oil and in areas where the environmental hazards associated with improper disposal are not generally recognized.

Available disposal options for used oil include:

- burning in incinerators with or without pollution control equipment;
- dumping in a sanitary landfill;
- solidification followed by disposal in a secure landfill;
- landfarming;
- dumping into a municipal sewer system; and
- indiscriminate dumping.

The following sections discuss the environmental risks associated with each of these alternatives and summarize recommended practices for the disposal of used oils.

6.2 Assessment of Practices and Alternatives

6.2.1 Incineration. There are two basic categories of incinerators used for the disposal of used oils:

- small incinerators; these are low capacity municipal or private burners designed primarily for the disposal of municipal solid wastes; these incinerators typically do not have pollution control equipment or high stacks; and
- commercial hazardous waste incinerators; these are burners designed specifically for the destruction of hazardous materials; they are constructed with flue gas treatment systems, adequate stack heights and are located to minimize adverse environmental effects.

The effects of used oil disposal in small incinerators would be similar to those described previously for space heaters and small boilers with uncontrolled emissions. Discharges of metals, halide acids and certain organics would be of concern, particularly if more than one burner operates in a given area. Negative effects would be exacerbated by poor control over used oil quality and the disposition of potentially contaminated solid residuals which accumulate in the incinerator.

The approval requirement for small municipal solid waste incinerators in the Province of Ontario depends on their capacity. Different requirements are specified for two capacity classes of incinerators, those above and below a 100 t/d design capacity.

Hazardous waste incinerators use high combustion temperatures under controlled air addition conditions to destroy harmful compounds. Sophisticated air pollution control equipment is used to prevent the release of particulate, sulphur dioxide, oxides of nitrogen, hydrogen chloride and any products of incomplete combustion. The incineration technologies most commonly used for the destruction of hazardous wastes include (U.S. EPA,1985):

- liquid injection;
- rotary kiln;
- fluidized bed; and
- multiple hearth.

The operating principles and general applications of these technologies are summarized in Table 41. Flue gas treatment systems commonly used with these incinerators include wet and dry scrubbers, electrostatic precipitators, baghouses and secondary combustion chambers.

Used oils have a high heating value relative to many hazardous wastes and could be used to reduce incinerator supplemental fuel requirements. In this case, the destruction of oils becomes a controlled burning end use rather than disposal since the oil's heating value is used to reduce virgin fuel consumption. From an environmental perspective this end use would be desirable because contaminated flue gas emissions and solid residuals are effectively controlled. In practice, however, widespread application is unlikely because the number of available incinerators is relatively small and because the costs of processing, transportation and equipment is such that a significant fee has to be levied for used oil disposal. Used oil generators are unlikely to utilize this end use when alternative markets pay for their used oil.

6.2.2 Landfilling. Large quantities of used oil have been disposed of in landfills for many years. Unfortunately, the landfills used do not incorporate the features necessary to protect the environment from used oil contaminants. A significant portion of landfilled oil has been directed to small municipal or personal dumps in rural areas that are not designed or operated with the protection of local resources as a key consideration. Used oils deposited in these facilities can pose a significant threat to groundwater and soil quality, increase metal levels in surrounding vegetation, and compromise local air quality through the emission of volatile compounds and degradation products.

TABLE 41 SUMMARY OF COMMONLY USED INCINERATION TECHNOLOGIES (from U.S. EPA, 1985)

Type	Process Principle	Application	Combustion Temperature (°C)	Residence Time
Rotary Kiln	waste is burned in a rotating refractory cylinder	any combustible solid, liquid, or gas	800 to 1 700	seconds for gases to hours for liquids and solids
Single Chamber/ Liquid Injection	wastes are automized with high pressure air or steam and burned in suspension	liquid and slurries which can be pumped	700 to 1 700	0.1 to 1 second
Multiple Hearth	wastes descend through several grates to be burned in increasingly hotter combustion zones	sludges and granulated solid wastes	750 to 1 000	up to several hours
Fluidized-Bed	waste is injected into an agitated bed of heated inert particles; heat is efficiently transferred to the wastes during combustion	organic liquids, gases	750 to 900	seconds for gases and liquids; minutes for solids

Used oils would require solidification prior to disposal to reduce their leaching potential and to fix contaminants within a stable physical matrix. Cement, lime, fly ash and soil can be used in various proportions and combinations as solidifying agents.

The direction of used oils to authorized hazardous waste landfills would be an environmentally acceptable disposal option. However, this alternative is not likely to be widely accepted for the following reasons:

- the complexities of processing and solidifying used oils for landfill disposal are such that the operation could only be done at a facility designed specifically for special and hazardous wastes which are continuously monitored and maintained by personnel experienced in the handling of hazardous materials;

- costs for transporting oils to the small number of appropriate landfills (likely to ever be available) would be high for most used oil generators;
- landfill disposal charges would have to be high to recover the large capital expenditures involved; and
- the landfilling of used oil will be regulated in the near future (pers. comm. Campbell, 1987).

A federal-provincial task force on landfilling of hazardous wastes is presently formulating criteria for wastes which will be accepted for landfilling. The intent of the criteria is to ensure hazardous waste pretreatment by the best available control technology prior to landfilling. Criteria which will prohibit the landfilling of used oil are:

- it is a liquid waste or it may exist as a free liquid within a solid waste;
- it contains more than 1 weight percent of liquid Total Organic Carbon;
- it is flammable;
- it may contain more than 0.1 wieght percent of halogenated organic carbon wastes; and
- it is not to be diluted prior to landfilling.

These criteria will prevent the landfilling of used oil if implemented for used oils in provincial and territorial jurisdictions, unless it is solidified or pretreated to meet these criteria prior to disposal.

6.23 **Landfarming.** Landfarming is a technique whereby hydrocarbon materials are applied to soil and biologically degraded through microbial action. Oils are applied by truck and mixed with the upper layer of soil using a farm type disc aerator. Lime and nitrogen are occasionally added to maintain an acceptable soil pH and encourage bacterial growth (Grove, 1978).

Landfarming has been used for a number of years by the petroleum industry for the disposal of oily residues. Landfarming of used oils has not been as common; however, several experimental applications have been evaluated (Rudolph, 1978). While these studies demonstrated that used oils can be degraded by land application under the appropriate conditions, they did not characterize the long-term environmental effects of this practice.

In 1984, the University of Oklahoma completed a study on the long-term effects of landfarming (Streebin et al., 1984). The investigators examined oil metal and organic pollutant levels at three abandoned landfarming sites which had been used to treat oily residues from refinery operations. The similarity of these wastes with used oils varied; however, many of the study findings are relevant to used oil landfarming. Some of the principal conclusions were:

- vertical migration of oil at the study sites did not extend below 50 cm from the soil surface;
- metals were immobilized within the upper 25 cm of soil;
- soil pore water samples exhibited barium, iron and manganese concentrations which exceeded local drinking water standards;
- polynuclear aromatic compounds and phenols were detected at parts per billion levels in the unsaturated zone of the study site soils;
- volatile hydrocarbons may continue to be emitted during tilling for a period of years after landfarming operations have been discontinued; and
- oil concentrations in the soil may not approach background levels for many years after the landfarming site has been decommissioned.

The University of Oklahoma study demonstrated that landfarming can have significant long-term environmental effects which will impose constraints on the future use of the affected area for many years.

The Wastewater Technology Centre (WTC) is developing a Code for Landfarming Petrochemical Wastes for the Petroleum Association for the Conservation of the Canadian Environment (pers. comm. Campbell/Bulman, 1987). The WTC favours a 1 weight percent oil-in-soil content as a rule of thumb. A 3 weight percent content is considered an absolute maximum. These numbers are based on a one hectare plot of land to a depth of 15 cm weighing 2×10^6 kg. The researchers at the WTC suggests the use of site rotation in landfarming and that oils containing aromatic hydrocarbons be given special consideration, as aromatic compounds tend to degrade much slower than other oil compounds when landfarming oils.

6.2.4 Sewer Disposal. A significant portion of the used oil generated by individuals who change their own automotive oil ends up in municipal sewer systems. Brinkman, Fennelly and Surprenant (1984) examined the environmental significance of these discharges. In laboratory simulations they determined that 90% of the used oil constituents would be associated with particulate matter in the urban runoff. They suggested that because particulate and free oils can be removed by contemporary treatment facilities, the used oil constituents in the water soluble component of the runoff would be of primary concern. The used oil constituent concentrations in the aqueous phase of the laboratory simulated runoff are summarized in Table 42. These levels suggest that the discharge of used oils to sewer systems should not prove harmful to

TABLE 42 CONTAMINANT LEVELS IN THE AQUEOUS PHASE OF A ONE TO ONE USED OIL/WATER MIXTURE (from Brinkman, Fennelly and Surprenant, 1984)

Contaminant	Samples: Composite Oil (μg/g)	Samples: Aqueous Phase (mg/L)
Organics		
Volatiles		
1,1,1-Trichloroethane	800	<1
Trichloroethylene	3000	<1
Tetrachloroethylene	110	<1
Benzene	75	<1
Toluene	2800	<1
Semivolatiles		
Phenol	11	11.0
2,4,6-Trichlorophenol	40	2.0
N-Nitrosodiphenylamine	116	1.0
Naphthalene	440	1.4
Phenanthrene/Anthracene	150	<0.1
Pyrene	62	<0.1
Benzo(a)pyrene	< 10	<0.1
Pesticide: 4,4-DDE	94	0.5
PCB (Arochlor 1260)	34	<0.1
Inorganics		
Arsenic	8.1	<0.03
Barium	61.4	0.01
Calcium	986	3.9
Chromium	7.7	<0.01
Copper	33.8	<0.01
Iron	214	2.3
Lead	1090	<0.02
Magnesium	212	1.63
Manganese	14.2	0.01
Nickel	3.7	<0.01
Sodium	257	58.3
Zinc	735	0.26

most municipal treatment works and that many of the potentially significant contaminants (e.g., phenols) would be reduced to acceptable levels by typical treatment systems. However, the investigators went on to point out that a relatively small proportion of the urban population is served by stormwater treatment systems. They stated that because concentrations of some contaminants shown in Table 42 exceed recognized stream discharge requirements, sewer disposal of used oil represents a practice which is potentially harmful to the large percentage of the urban population living in areas where stormwater control is not practiced and to other populations downstream of stormwater discharge points.

6.2.5 Indiscriminate Dumping. A large portion of used oil generated by "do-it-yourself" oil changers is dumped at source. In urban areas, backyards and alleys are favoured while small pits, fields and drainageways are often used in rural areas. This is perhaps the most undesirable form of used oil disposal because of the lack of control over environmental effects. When used oil is dumped indiscriminately, all of the negative effects associated with practices like road oiling and landfarming are exacerbated because contaminants have not necessarily been confined to designated areas. The chance for contamination of productive soils and water bodies is relatively great as is the probability of direct ingestion of used oil contaminants by humans (particularly children) and livestock.

6.3 Current Practice in Canada

Detailed breakdowns of used oil quantities directed to the various disposal alternatives described previously are not available. Table 43 provides some appreciation for the possible scale of used oil disposal in Canada. While quantities reported to be landfilled or incinerated are large in some jurisdictions, perhaps even more significant are the generally large volumes of oil unaccounted for. Much of this oil is undoubtedly disposed of in small municipal landfills, sewers or by indiscriminate dumping.

Oil volumes reported as landfilled or incinerated are probably not directed to facilities capable of handling used oil in an environmentally acceptable manner. Very few authorized hazardous waste landfills are available and most municipal incinerators are not equipped with adequate flue gas emission control equipment. In summary, it can be said that only a small portion of the used oil disposed of in Canada is handled in a manner that effectively controls the environmental risks involved.

6.4 Recommended Practices

Used oils should be disposed of by burning in a hazardous waste incinerator or by solidification followed by disposal to an authorized hazardous waste landfill. The other options described previously do not provide adequate control of environmental risks and should not be considered.

TABLE 43 USED OIL DISPOSAL PRACTICES IN CANADA (from Proctor and Redfern Ltd. et al., 1984)

Jurisdiction	Percentage of Waste Oil Generated that is Landfilled or Incinerated	Percentage of Waste Oil Generated that is Unaccounted for
British Columbia	26	17
Alberta	5	36
Saskatchewan	57	NA
Manitoba	NA	NA
Ontario	NA	70*
Quebec	NA	55
New Brunswick	3	58
Nova Scotia	NA	NA
Prince Edward Island	74	NA
Newfoundland	22	35
Northwest Territories and Yukon	NA	NA
Canada	4	65

* the source data are somewhat inconsistent, particularly for Ontario which is also reported to have re-refined 91×10^6 L during 1983; when using this number, the unaccounted percentage for Ontario is reduced to 20%

NA - not available

Large-scale disposal of oils should not be viewed as a desirable used oil management strategy. Disposal does not allow the lubricating and/or heating value of the oil to be utilized; therefore, the overall costs of disposal are high. Environmentally acceptable disposal, however, should be encouraged for highly contaminated and unmarketable oils which would otherwise be used or disposed of in inappropriate ways.

6.5 Costs

Costs for environmentally acceptable disposal (by incineration or treatment/authorized hazardous waste landfilling) are generally very high. Credit does not accrue to society from the marketing of a product (e.g., lube oil, fuel). Collection/transportation costs are high because few appropriate facilities are available. In addition, the large capital and operating expenditures required for hazardous waste facilities generate high disposal charges.

For potential costs resulting from the direction of 20% of used oil generated in each province to environmentally acceptable disposal facilities see Table 44. These costs were based on the following unit costs derived from in-house information and liquid incineration cost data supplied by a hazardous waste facility operator (Henderson, 1987):

Disposal Cost Component	Unit Cost (¢/L)
Incineration (of high Btu liquid waste)	10
Treatment/Authorized Hazardous Waste Landfilling	30
Collection/Transportation	10

The collection/transportation cost ($.10/L) is an average figure. In reality, costs would vary with distance to the nearest treatment/disposal facility and would likely be prohibitive in many locations. Adequate incineration and landfilling services are available at only a few locations in Canada (e.g., Tricil facilities at Sarnia, Ont. and Ville Mercier, Que.). When new facilities currently proposed or under construction in Ontario, Quebec and Alberta come on line, large portions of the country will still be faced with high transportation costs for environmentally acceptable disposal of used oils.

Table 44 is not intended to show a probable used oil management strategy but rather to provide some appreciation for the scale of costs involved for the disposal of a significant quantity of used oils. Economically, the disposal of used oils is far less desirable than re-refining or controlled burning. Disposal should be considered only for highly contaminated oils which cannot be cost-effectively recycled or reused in an environmentally acceptable manner.

TABLE 44 ESTIMATED COSTS FOR DIRECTING USED OILS TO ENVIRONMENTALLY ACCEPTABLE DISPOSAL FACILITIES (1987 $ Cdn.) (from Proctor and Redfern Ltd. et al., 1984)

			Total Disposal Costs for 20% of Used Oil Generated*	
Province	Oil Generated ($x10^6$ L/yr)	20% of Used Oil Generated ($x10^6$ L/yr)	Disposal Incineration (1000 $/yr)	Disposal by Solidification/ Secure Landfilling (1000 $/yr)
British Columbia	41	8.2	1 640	3 280
Alberta	51	10	2 000	4 000
Saskatchewan	22	4.4	880	1 760
Manitoba	14	2.8	560	1 120
Ontario	173	35	7 000	14 000
Quebec	64	13	2 600	5 200
Atlantic Provinces	29	5.8	1 160	2 320
Territories	NA	-	-	-
Total	394	79	15 800	31 600

* includes collection/transportation cost; NA = not available

7 SOCIO-ECONOMIC ANALYSIS

7.1 Introduction

This chapter presents an overview of the potential social benefits resulting from alternative approaches to used oil management. Social benefits are discussed in terms of: direct income effects and direct employment effects.

Due to the limited scope of this study and the wide variety of possible used oil management scenarios, the analysis of socio-economic effects was carried out in a general manner. Rigorous cost-benefit, cost-effectiveness, macro-economic analyses or the like were not conducted.

7.2 Socio-economic Aspects

7.2.1 Direct Income Effects. In Chapter 2, it was estimated that Canada currently generates about 394×10^6 L of used oils annually. Of these, approximately 24% are re-refined and 17% are collected for other reuse practices.

For the purpose of this analysis, two used oil recovery scenarios, 20% and 90%, were arbitrarily selected to be representative of worst and best case scenarios, respectively. The recovery levels were then applied to four used oil management alternatives to compare the expenditures associated with each. Tables 45 and 46 present these relative expenditures by province for the two recovery scenarios. It is assumed that all of the oil recovered in a province is directed either to re-refining, burning, road oiling or disposal. This presentation is not intended to be representative of probable management strategies but rather to highlight the relative expenditures associated with various alternatives. In reality, provincial management strategies would likely utilize more than one recycling or end-use option.

The expenditures in Tables 45 and 46 include collection/transportation costs and are based on the following ranges of unit costs:

Alternative	Unit Cost (¢/L)
Re-refining	23 to 54
Burning	9.0 to 25
Road Oiling	5.0 to 18
Disposal	20 to 40

TABLE 45 TOTAL ANNUAL USED OIL MANAGEMENT EXPENDITURES AT A RECOVERY RATE OF 20%

Province	Used Oil Generated ($x10^6$ L/yr)	20% of Used Oil Generated ($x10^6$ L/yr)	Expenditures (1000's $/yr) (1987 $ Cdn.) Re-Refining	Burning	Road Oiling	Disposal
British Columbia	41	8.2	1 900 to 4 400	740 to 2 100	400 to 1 500	1 600 to 3 300
Alberta	51	10.2	2 300 to 5 500	920 to 2 600	510 to 1 800	2 000 to 4 000
Saskatchewan	22	4.4	1 000 to 2 400	400 to 1 100	220 to 800	880 to 1 800
Manitoba	14	2.8	640 to 1 500	250 to 700	140 to 500	560 to 1 100
Ontario	173	34.6	8 000 to 18 700	3 100 to 8 700	1 700 to 6 200	6 900 to 13 800
Quebec	64	12.8	2 900 to 6 900	1 200 to 3 200	640 to 2 300	2 600 to 5 100
Atlantic Provinces	29	5.8	1 300 to 3 100	520 to 1 300	290 to 1 000	1 200 to 2 300
Total	394	78.8	18 040 to 42 500	7 130 to 19 700	3 900 to 14 100	15 740 to 31 400

TABLE 46 TOTAL ANNUAL USED OIL MANAGEMENT EXPENDITURES AT A RECOVERY RATE OF 90%

Province	Used Oil Generated ($x10^6$ L/yr)	20% of Used Oil Generated ($x10^6$ L/yr)	Expenditures (1000's $/yr) (1987 $ Cdn.) Re-Refining	Burning	Road Oiling	Disposal
British Columbia	41	37	8 600 to 19 800	3 300 to 9 500	1 800 to 6 800	7 200 to 14 900
Alberta	51	46	10 400 to 24 800	4 100 to 11 700	2 300 to 8 100	9 000 to 18 000
Saskatchewan	22	20	4 500 to 10 800	1 800 to 5 000	990 to 3 600	4 000 to 8 100
Manitoba	14	13	2 900 to 6 800	1 100 to 3 200	630 to 2 300	2 500 to 5 000
Ontario	173	156	36 000 to 84 200	14 000 to 39 200	7 700 to 27 900	31 000 to 62 100
Quebec	64	58	13 100 to 31 100	5 400 to 14 400	2 900 to 10 400	117 700 to 23 000
Atlantic Provinces	29	26	5 900 to 14 000	2 300 to 5 900	1 300 to 4 500	5 400 to 10 400
Total	394	354	81 400 to 191 500	32 000 to 88 900	17 620 to 63 600	70 800 to 141 500

The cost ranges for re-refining, burning and disposal were developed from the estimates appearing in Sections 4.5, 5.5 and 6.5, respectively. The ranges presented account for world oil price variations, economies of scale and differences in process efficiencies. The road oiling costs were derived from estimates appearing in E.R.A. Consulting Economists, Inc. (1979).

It should be noted that the estimates appearing in Tables 45 and 46 represent expenditures, not the overall costs of each used oil handling alternative. All of these options with the exception of disposal, produce a product with some marketable value (i.e., lube oil, heat/steam, dust suppressant) which under favourable conditions, makes the alternative self-supporting. Disposal is unique in as much as any expenditures incurred are not defrayed by the sale of a commodity generated by the process.

Under the 20% recovery scenario (Table 45), re-refining would involve estimated expenditures ranging from $18 million to $43 million per annum. Burning expenditures range from $7 million to $20 million per annum, while road oiling expenditures are somewhat lower. Disposal expenditures vary from as low as $16 million to as high $32 million per year, depending primarily on the method of disposal selected (i.e., incineration or treatment/secure landfilling).

Table 46 presents expenditures for the 90% recovery scenario. Re-refining expenditures range from $82 million to $192 million per year. Expenditures for burning vary from $32 million to $89 million per year, while those for road oiling range from $18 million to $64 million per year. Disposal expenditures vary from $71 million to $142 million per year.

The highest expenditures would be generated in Ontario where the largest amount of used oil is currently generated. About 45% of all Canadian used oils are generated in Ontario. Quebec, being the second largest used oil generator would incur the second highest expenditures resulting from used oil management.

It is estimated that labour costs constitute roughly 30% to 40% of the total expenditures for used oil management, depending on the technology selected. The remainder of the expenditures would be for material and subcontracted services. Depending on the extent of import requirements, whether in labour, material or services, a portion of the total expenditures would leave the Canadian economy. It is anticipated that most of the labour income would likely remain in Canada; however, it is possible that a portion of the income accruing to material and subcontracted services would be spent outside of Canada on import goods and services, resulting in some income leakage.

Through spending and re-spending of labour income, mainly as wages and salaries, induced income would be generated. Also, a portion of the income associated with material and service purchases would generate indirect income as wages and salaries, and these in turn would generate more induced income, through spending and re-spending. Depending on the extent of income leakage, the indirect and induced income effects combined can range from a multiple of 0.1 upward. The limited information base, however, does not allow an analysis of these secondary effects.

This income effect analysis did not take into account the income displacement effect of some of the used oil management approaches. Re-refining, burning and road oiling activities would displace activities in other industries. For instance, re-refining using used oils would displace conventional lube oil refining to some extent. The net income effect of re-refining, therefore, is much smaller than that presented earlier. It has been noted that re-refining used oils involves almost four times higher labour costs and higher costs in material and services in general than conventional lube oil refining (The Canadian Association of Re-refiners, 1987). This suggests that for the same level of output, re-refining would generate a higher level of income than conventional refining.

Similarly, using used oils as fuel would displace other types of fuels otherwise used for burning or heating purposes. While it is recognized that some income displacement would result if used oils are burned, estimation of the magnitude of this displacement is beyond the scope of this evaluation.

Given these considerations, the estimated income effects presented in Tables 45 and 46 should be considered as gross rather than net effects. By comparison, it appears that re-refining would generate the highest gross income effect. Although disposal may produce gross income effects similar to re-refining, it does not generate a marketable product. The other methods (i.e., burning and road oiling) both generate fewer gross income benefits and are less desirable from an environmental and resource conservation standpoint than re-refining.

7.2.2 Direct Employment Effects. Direct employment effects are the results of income generated from used oil management practices. As noted in the previous section, labour costs represent between 30% and 40% of the total management expenditures, depending on the management strategy selected. Tables 47 and 48 show estimates of the approximate labour expenditures relating to re-refining, burning, road-oiling and disposal.

Order-of-magnitude estimates of the potential direct employment effects can be made by assuming that the cost to create a person-year job would average $30 000.00 for all four approaches to used oil management. This cost would include wages or salaries and other non-wage related costs such as fringe benefits and training and relocation costs. It is recognized that in reality, average job costs would likely vary among the different used oil handling alternatives. The results of the analysis should therefore be viewed with caution.

At the 20% used oil recovery level, re-refining in Canada as a whole would create approximately 180 to 430 person-year jobs, burning would create 70 to 200 person-year jobs, road-oiling would create 40 to 140 person-year jobs and disposal would create 210 to 420 person- year jobs (Table 49). The bulk (about 44%) of the jobs under any of the four alternatives would be located in Ontario. Quebec and Alberta would have the second and third highest levels of employment, respectively.

TABLE 47 ANNUAL LABOUR EXPENDITURES AT A USED OIL RECOVERY RATE OF 20%

Province	Expenditures (1000 $/yr) (1987 $ Cdn.)			
	Re-refining*	Burning*	Road Oiling*	Disposal**
British Columbia	570 to 1 300	220 to 630	120 to 450	640 to 1 300
Alberta	690 to 1 700	280 to 780	150 to 540	800 to 1 600
Saskatchewan	300 to 720	120 to 330	70 to 240	350 to 720
Manitoba	190 to 450	80 to 210	40 to 150	220 to 440
Ontario	2 400 to 5 600	930 to 2 600	510 to 1 900	2 800 to 5 500
Quebec	870 to 2 100	360 to 960	190 to 690	420 to 2 000
Atlantic Provinces	390 to 930	160 to 390	90 to 300	480 to 920
Total	5 410 to 12 800	2 150 to 5 900	1 170 to 4 270	5 710 to 12 480

* based on the assumption that labour costs represent 30% of total alternative costs
** based on the assumption that labour costs represent 40% of total alternative costs

TABLE 48 ANNUAL LABOUR EXPENDITURES AT A USED OIL RECOVERY RATE OF 90%

Province	Expenditures (1000 $/yr) (1987 $ Cdn.)			
	Re-refining*	Burning*	Road Oiling*	Disposal**
British Columbia	2 600 to 5 900	990 to 2 900	540 to 2 000	2 900 to 6 000
Alberta	3 100 to 7 400	1 200 to 3 500	690 to 2 400	3 600 to 7 200
Saskatchewan	1 400 to 3 200	540 to 1 500	300 to 1 100	1 600 to 3 200
Manitoba	870 to 2 000	330 to 960	190 to 690	1 000 to 2 000
Ontario	10 800 to 25 300	4 200 to 11 800	2 300 to 8 400	12 400 to 24 800
Quebec	3 900 to 9 300	1 600 to 4 300	870 to 3 100	4 700 to 9 200
Atlantic Provinces	1 800 to 4 200	690 to 1 800	390 to 1 400	2 200 to 4 200
Total	24 470 to 57 300	9 500 to 26 760	5 280 to 19 090	28 400 to 56 600

* based on the assumption that labour costs represent 30% of total alternative costs
** based on the assumption that labour costs represent 40% of total alternative costs

At the 90% recovery level, job creation would be proportionately higher than at the 20% level. Re-refining would create 820 to 1 900 person-year jobs in Canada; burning, 320 to 890 person-year jobs; road-oiling, 180 to 640 person-year jobs; and disposal, 950 to 1 890 person-year jobs (Table 50). Again, Ontario would receive the largest portion of the total employment, followed by Quebec and Alberta.

The person-year jobs listed in Tables 49 and 50 do not include transportation sector jobs. Each of the four used oil reuse options would create jobs in the transportation sector due to the necessity of collecting used oil and transporting it to the reuse locations.

As discussed previously, not all of these jobs would be new jobs to the Canadian economy, as some would displace other jobs which would otherwise be created in different industries. For instance, some re-refining jobs would displace jobs in conventional crude oil refining.

This analysis suggests that re-refining would generally create the highest level of gross employment relative to other likely used oil handling options. To fully understand the socio-economic effects in terms of employment relating to used oil management, however, net effects should also be considered. The analysis of net effects should be considered as a subject for a more detailed study.

TABLE 49 ANNUAL EMPLOYMENT (person-year jobs) GENERATED BY USED OIL MANAGEMENT EXPENDITURES AT A RECOVERY RATE OF 20%

Province	Number of Jobs			
	Re-refining	Burning	Road Oiling	Disposal
British Columbia	19 to 43	7 to 21	4 to 15	21 to 43
Alberta	23 to 57	9 to 26	5 to 18	27 to 53
Saskatchewan	10 to 24	4 to 11	2 to 8	12 to 24
Manitoba	6 to 15	3 to 7	1 to 5	7 to 15
Ontario	80 to 190	31 to 87	17 to 63	93 to 180
Quebec	29 to 70	12 to 32	6 to 23	14 to 67
Atlantic Provinces	13 to 31	5 to 13	3 to 10	16 to 31
Total	180 to 430	71 to 197	38 to 142	190 to 413

TABLE 50 ANNUAL EMPLOYMENT (person-year jobs) GENERATED BY USED OIL MANAGEMENT EXPENDITURES AT A RECOVERY RATE OF 90%

	Number of Jobs			
Province	Re-refining	Burning	Road Oiling	Disposal
British Columbia	87 to 200	33 to 97	18 to 67	97 to 200
Alberta	103 to 250	40 to 120	23 to 80	120 to 240
Saskatchewan	47 to 110	18 to 50	10 to 37	53 to 110
Manitoba	30 to 70	11 to 32	6 to 23	33 to 67
Ontario	360 to 840	140 to 390	77 to 280	410 to 830
Quebec	130 to 310	53 to 140	29 to 100	160 to 310
Atlantic Provinces	60 to 140	23 to 60	13 to 47	73 to 140
Total	817 to 1 920	318 to 889	176 to 634	946 to 1 897

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