CODE OF PRACTICE FOR USED OIL MANAGEMENT IN CANADA

by

Monenco Consultants Ltd.

for the

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Environmental Protection
Conservation and Protection
Environment Canada

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FOREWORD

This Code of Practice describes environmentally sound options for the handling, storage, collection, transportation, recycling, reuse and disposal of used oils in Canada.

Used oil, as referred to in this Code of Practice, is a lubricating oil which has become unsuitable for its original purpose due to the presence of impurities or the loss of original properties. It does not include oils derived from animal or vegetable fats.

The Code does not treat used oil exclusively as a hazardous waste. Used oil may or may not be designated as a hazardous waste depending on the types and amounts of chemical impurities it contains.

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1 INTRODUCTION

Systems for the management of used oil are required because of the large volumes generated annually in Canada, their potential for recycle and the negative environmental implications of improper reuse or disposal.

This Code of Practice describes environmentally sound options for the handling, storage, collection, transportation, recycling, reuse and disposal of used oils in Canada. It is intended to provide guidance for used oil generators and to regulatory authorities in the formulation of provincial or regional used oil management strategies.

1.1 Used Oil Definition

Used oil (as referred to in this Code of Practice) is 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 oils derived from animal or vegetable fats nor does it include crude or fuel oils spilled onto land or water and wastes from petroleum refining operations. The following categories of used oil are covered by this Code of Practice:

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

Used oil primarily contains hydrocarbons; however, it may contain additives (e.g., a total of 14 volume % additives of detergents and viscosity improvers in lube oils for gasoline engines). It contains physical and chemical impurities (e.g., solids, metals and chlorinated organics) due to physical contamination and chemical reactions occurring during its use. Contamination of used oil may also occur from mixing with other oily fluids or fluid wastes when it is collected for recycling.

This Code of Practice does not treat used oil exclusively as a hazardous waste. Used oil may or may not be designated as a hazardous waste depending on the types and amounts of chemical impurities it contains. For example, if used oil contains 50 ppm or more PCBs, it is designated a hazardous waste in most Canadian jurisdictions.

1.2 Existing Regulations

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

1.2.1 Federal Regulations.

In Canada, there are no federal regulations which deal specifically with the management of used oils. The Transportation of Dangerous Goods (TDG) Act and regulations thereunder 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 which are contaminated with hazardous substances or which are dangerous will fall under the TDG regulations.

The TDG regulations define a hazardous substance as a product or substance that is included in Division 2 of Class 9 in List II of Schedule IV. 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 the following in excess of 100 ppm:

- lead,
- zinc,
- trichloroethane,
- trichloroethylene,
- benzene,
- toluene,
- xylene, and
- PCBs (>50 ppm content).

The TDG regulations classify liquids or mixtures of liquids as dangerous and flammable under Class 3 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).

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

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 I 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

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.

1.2.2 **Provincial Regulations.** Used oil handling and disposal is controlled through provincial regulations and guidelines. 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, however, 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 under development. Used oil may be sprayed on roads for dust suppression provided the oil does not originate from electrical equipment and does not contain more than 5 ppm of PCBs. Road oiling in Ontario is currently under review because of 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. 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 oil (Table 1).

2 CHARACTERIZATION AND GENERATION OF USED OILS

2.1 Virgin Oil Characteristics

The nature of used oil is determined in part by its characteristics in the virgin state. Lubricating, metal working, hydraulic, and insulating oils are comprised of petroleum base stocks mixed with various additives. The general purpose of the additives is to enhance and prolong the performance characteristics and useful life of the base oil (Table 2). Lubricating characteristics are enhanced by adding chemicals which:

- stabilize the temperature dependence of the oil viscosity;
- prevent oil tackiness;
- disperse solid particles; and
- maintain lubricating characteristics under extreme hydraulic pressure.

Prolonged life is ensured by adding chemicals which:

- neutralize acids formed;
- form corrosion or oxidation preventing films;
- inhibit microbial growth; and
- minimize chemical degradation.

The amount and type of additives vary with the intended use of the oil. Hydraulic oils for example, contain very few additives, whereas lubricating oils typically contain 10% to 20% by volume. Table 3 provides a formulation of a typical lubricating oil for gasoline engines. The additives as well as their degradation products contribute impurities of metals (e.g., zinc, magnesium and calcium), organic and inorganic salts and chlorinated organics to the used oil.

2.2 Used Oil Characteristics

Contaminants, in addition to those originating from the virgin oil components, are imparted to the oil during use from the ingression of foreign compounds (e.g., metals and solids from friction wear as well as lead, soot and water, i.e., fuel combustion products). Contaminants are also imparted to the oil after its use. Contaminants are often present in used oil due to subsequent poor management practices (Franklin Associates Ltd., 1985). Used oil of various types, some of which contain chlorinated solvents or PCBs, become mixed.

Tables 4 and 5 characterize used oils with respect to physical properties and concentrations of potentially hazardous substances and show that:

- used oils can have a flash point below the 61°C temperature that classifies a material as "dangerous" according to the TDG regulations;

TABLE 2 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, phosphorous, 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 3 TYPICAL FORMULATION OF GASOLINE ENGINE OIL

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 (polyisobutylene)	5

- used oil can contain hazardous substances as defined in the EC or TDG regulations (i.e., PCBs in excess of 50 ppm, or lead, zinc, trichloroethane, trichloroethylene, benzene, toluene and xylene, each in excess of 100 ppm);
- the relatively low viscosities and heating values of some used oils indicate the presence of contaminants such as solvents, water and inorganic solids;
- used oils may exhibit elevated concentrations of a variety of metals, particularly lead and zinc; and
- the concentrations of organic contaminants in used oil, including non-use related chlorinated solvents, can be significant.

The extremely large water, plus sediment content of 99% as well as the extremely low viscosity of 0.01 cm^2/s (shown in Table 4) reveal the presence of waste oil samples and used oil samples heavily contaminated with solvents.

TABLE 4 SUMMARY OF PHYSICAL CHARACTERISTICS OF USED OILS (from Franklin Associates Ltd., 1985)

Parameter	Number of Samples	Range		Mean	Median
		Low	High		
Flash point (°C)	289	17	290	99	NA
Bottom sediment and water (%)	320	0	99	19	9
Water only (%)	36	0	67	11	5
Viscosity (cm^2/s at 38°C)	0.7	0.01	5.13	0.71	0.47
Specific gravity	48	0.67	0.98	0.89	0.89
Heating value kJ/kg	231	9630	53 600	38 370	40 000

2.3 Variations in Used Oil Characteristics

The characteristics of used lubricating, hydraulic, metalworking and insulating oils differ as a result of differences in virgin oil properties and use-related contaminants. 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 6. Gasoline engine oil and diesel engine oil serve as lubricants, while cutting and machine oils serve as metalworking fluids in the iron and steel fabrication industry. Hydraulic oils serve as a pressure transmitting fluid.

Table 6 also shows that engine (lubricating) oils are typically more contaminated than metalworking fluids which are, in turn, somewhat more contaminated than hydraulic fluids. The presence of at least low levels of organic solvents and PCBs in all oil types indicates that both automotive and industrial generators have a tendency to mix other materials with their used oils.

2.4 Recommended Segregation Practices

Used oil generators should segregate used oils at respective points of generation. They should not contaminate a segregated oil with an oily fluid which visually appears to be the same substance. The degree of segregation will depend on the amounts and variety of used oils generated. The following categories of segregation should be pursued:

- engine lubrication oils;
- hydraulic oils (including break and power stearing fluids);
- metalworking/cutting oils (never mix with anything but waste oils);
- insulating oils (if containing chlorinated organics, it should not be mixed with any other oil); and
- waste oils (including oily fluids, oil-in-water emulsions, greases and solvents).

Owners of service stations and lubrication facilities should consider the first two and last categories of segregation, whereas commercial and industrial generators should consider each of these categories when they are practical and economical.

TABLE 5 CONCENTRATION OF POTENTIALLY HAZARDOUS CONSTITUENTS IN USED OILS (from Franklin Associates Ltd., 1985)

Parameter	Number Samples Analyzed	Samples with Detected Contaminants: Number	Samples with Detected Contaminants: Percent	Mean Conc.** (ppm)	Median Conc.*** (ppm)	Conc. at 75th Percentile*** (ppm)	Conc. 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	1300	100 000
1,1,1-Trichloroethane	616	388	62	2 800	200	1300	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	1600	4000	9 500
Other Organics							
Benzene	236	118	50	961	20	110	300
Toluene	242	198	81	2 200	380	1400	4 500
Xylenes	235	194	82	3 390	550	1400	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

TABLE 6 COMPARISON OF POTENTIALLY HAZARDOUS CONSTITUENT LEVELS IN USED OILS BY SPECIFIC OIL TYPES (from Franklin Associates Ltd., 1985)

	Constituent Conc. in Gasoline Engine Oils (ppm)		Constituent Conc. in Diesel Engine Oils** (ppm)		Constituent Conc. in Hydraulic Oils (ppm)		Constituent Conc. in Cutting or Machine Oils (ppm)	
Parameter	Range	Median	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 to 18	200 to 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 2 400	15 (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 to 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 5 700	15 (14)
Xylenes	1 289	detectable conc.	1 817	- (1)	<2 to 700	7 (8)	<7 to 1 100	70 (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)***

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

3 COLLECTION AND TRANSPORTATION OF USED OIL

3.1 Collection

An estimated one-half of the recoverable used oil generated in Canada is currently collected by private companies. At least twenty-five companies are collecting used oil for the end uses of re-refining, burning, road oiling, or disposal. The collection services are confined to urban areas where distances and used oil availability makes it economical to collect. A larger than 50% portion of the recoverable used oil generated could be collected and managed for optimum end uses if organized collection systems were in place.

The effective collection and transport of used oils from the point of generation to recycling or end use locations are essential if the oils are to be utilized or disposed of in an environmentally acceptable manner. Used oils are typically collected by haulers who deliver the oil to local recyclers or users. The scope of the collectors' operations are limited geographically and vary with market conditions. In addition, collection operations of this type are designed primarily to meet the immediate needs of recyclers and users in the local area. They are not driven by the broader objectives of resource conservation and reduction of environmental risks which can be achieved through collecting a high proportion of the used oils generated. Rural areas are not as well served by collectors due to the large cost of transportation. An interdepartmental committee study showed that the spring 1986 price drop for crude oil caused a halt to used oil collection in several rural areas of Canada (pers. comm. Campbell, 1987). Nevertheless, the study also showed that a significant reduction in overall national collection volumes did not occur after the spring of 1986. That is, the drastic drop in the crude oil price did not cause a drastic drop in the collected used oil volumes.

Used oil recoveries in a given jurisdiction can be increased and stabilized through implementation of a centralized collection system of the type illustrated conceptually in Figure 1. This collection system includes the following components:

- used oil generator; this 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; this applies to small volume generators which do not have on-site storage equipment and therefore must transport used oils to facilities that do;

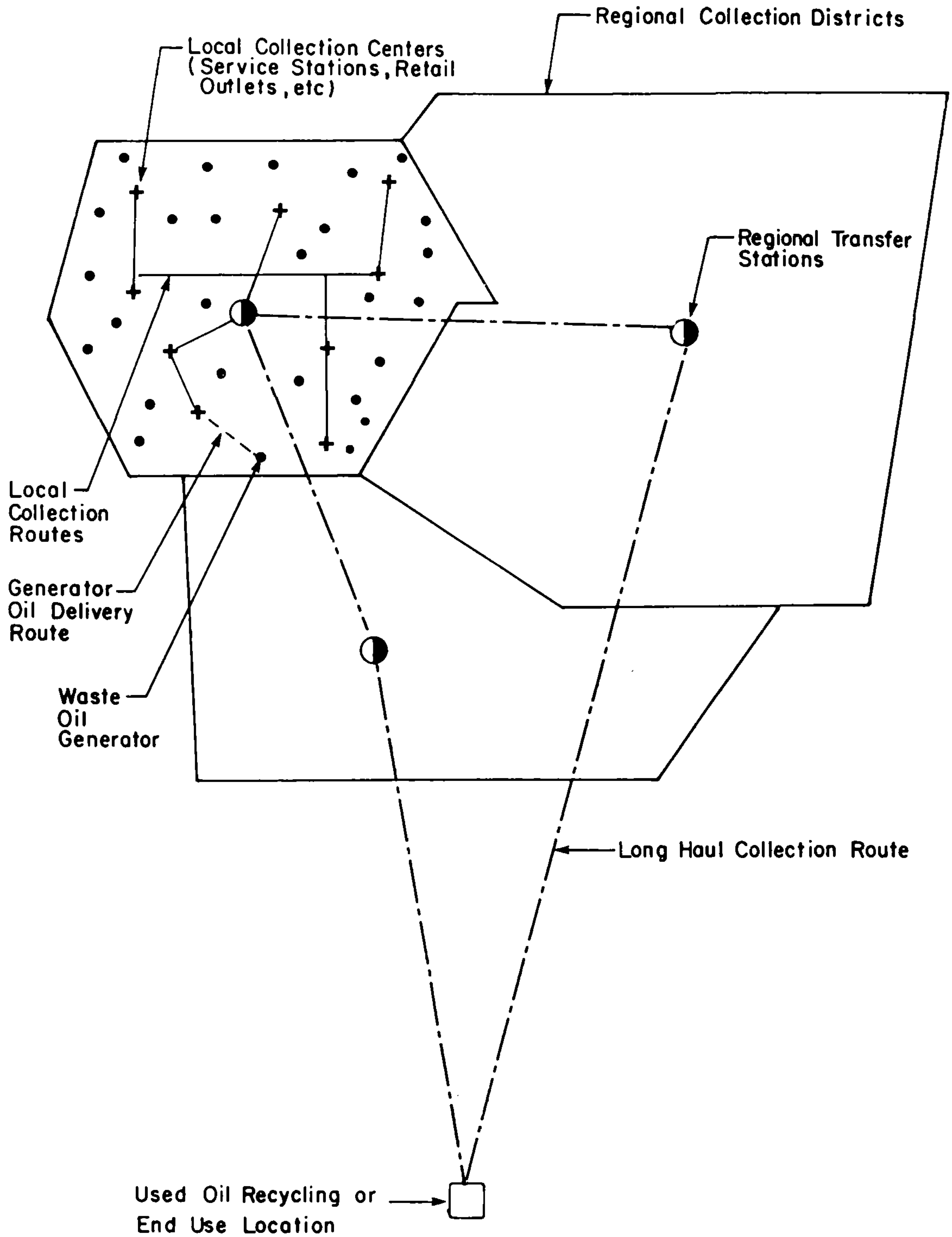

FIGURE 1 CONCEPTUAL ILLUSTRATION OF A USED OIL COLLECTION SYSTEM

- local collection centres; these 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; used oil collectors and/or processors follow these routes to collect oils from local collection centres and commercial and industrial operations with in-house storage equipment;
- regional transfer stations; oils from local collection centres are delivered to regional transfer stations equipped with underground oil storage vessels of a size sufficient to make long-haul transport of oils economically feasible;
- regional collection districts; each regional transfer station supports a collection district; districts are sized by considering the combined capital and operating costs associated with its collection system; large districts minimize unit capital costs for transfer stations but increase the operating (trucking costs for local collection; the optimum district area is that with the lowest total capital and operating cost; and
- long haul collection route; large highway tankers transport oils from the regional transfer stations to the recycling or end use location.

The collection system should be administered by a 'collection authority'. The collection authority may be a federal board which provides policy input to provincial and territorial boards which are the regional policy executors. The collection authority's mandate would be to develop and administer 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 which sell 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 haulers;
- provide sufficient economic incentives to long distance used oil transporters to guarantee the delivery of oils from the regional transfer stations to centralized oil users;
- identify environmentally appropriate users for the oils collected;
- coordinate the efforts of local and long distance haulers to ensure that used oil supplies match demand; and
- provide advice to used oil generators, local collection centres, haulers and the general public.

In addition, the collection 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 recycled products.

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, although it would not store or physically 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 would be utilized.

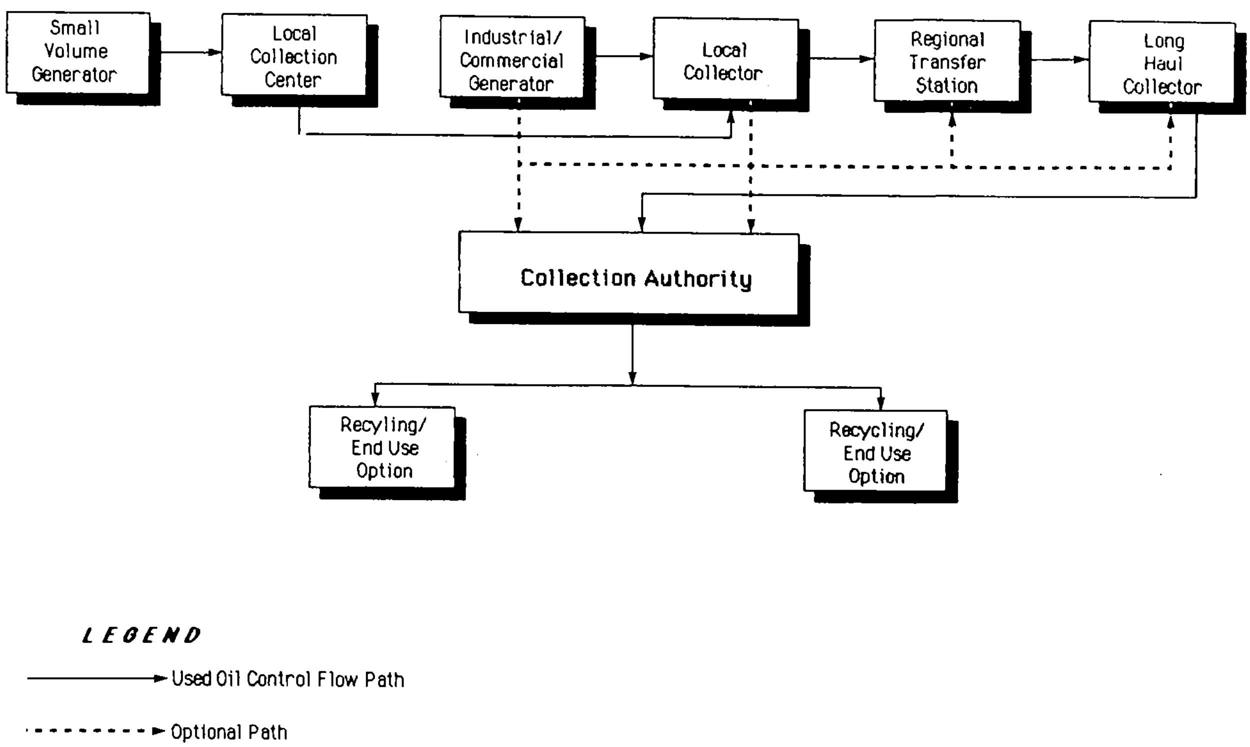

FIGURE 2 SCHEMATIC REPRESENTATION OF THE CONTROL OF USED OIL FLOWS IN A CENTRALIZED COLLECTION SYSTEM

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 which generate the greatest volumes of used oil.

The implementation of these collection systems will have a greater impact in the Canadian north where there are few collection systems and a larger number of "do-it-yourself" oil changers than in the south.

3.2 Transportation

Used oils should be subject to more rigorously controlled transportation practices than virgin oils because of the contaminants they contain. Used oils may or may not be subject to the Transportation of Dangerous Goods (TDG) Act and regulations depending on flash point and the content of hazardous substances. Used oils contaminated with high levels of gasoline and solvents may have flash points below 61°C and therefore fall under the TDG regulations. They may contain metals and chlorinated organics in excess of the levels designating the oil as hazardous under the TDG regulations (i.e., lead, zinc, trichloroethane, trichloroethylene, benzene, toluene and xylene contents of more than 100 ppm and PCB contents of more than 50 ppm). Given the difficulties for individual generators to develop precise characterizations of their used oils, consideration should be given to requiring all transporters to follow the TDG regulations regardless of the suspected flash point or content of hazardous substances. Such a requirement, however, should be implemented only if exemption procedures are in place for generators to regularly demonstrate that their used oils are not generally hazardous. Exemptions should also be applied for small volume generators transporting used oils to local collection centres. Application of the TDG regulations to the movement of used oils provides the following benefits:

- documentation; the regulations require that documents outlining the nature and quantity of materials transported remain with the shipment at all times; this will assist those regulating the flow of oils in a centralized collection system to control the disposition of used oils;
- safety marks; containers, vehicles and handling facilities used in the transport of dangerous goods must be identified using standardized labels or placards; these markings allow handling personnel to use appropriate procedures and provide for immediate identification of the material in the event of an accident or spill;
- training; the regulations require that any person who handles, offers for transport or transports dangerous goods must be trained or working under the direct supervision

of a trained person; this requirement reduces environmental risks by minimizing the potential for the mishandling of used oils; and

- reporting; the regulations encourage the timely mitigation of spills by requiring those in control of the shipment to notify the police, their employer, the consignor of the goods and the owner of the road vehicle involved, in the event of a release of dangerous substances.

In addition to requiring compliance with the TDG regulations, used oil haulers should be compelled to rinse tankers previously used to transport other materials. This will reduce the potential for contamination of used oils in transport.

3.3 Spill Response and Cleanup

Spills of used oil that occur during transportation or at storage sites can seriously contaminate soil, groundwater and surface water quality if they are not cleaned up quickly.

Preventive action is the most cost-effective means of reducing the potential for environmental damage because of the high cost of spill cleanup. These measures include: maintenance of inventories for loss control and inventory reduction, leak detection devices and containment dykes for storage structures and equipment, as well as tank and equipment inspection, procedural checklists and employee training.

A contingency plan is necessary to clearly identify corporate and staff responsibilities in the event of a spill, and provide up-to-date procedures for contacting cleanup crews and notifying corporate, municipal and provincial authorities. The lack of an effective and current contingency plan can lead to a very expensive cleanup.

When major spills do occur, the oil should be contained as quickly and completely as possible to minimize the extent of environmental effects. Appropriate authorities (e.g., police, municipal and provincial environmental officials) should be notified immediately after initial containment efforts are complete. Spills on land can then be covered with absorbent materials and removed. Underlying and surrounding soils which have become saturated with used oils should also be removed. Cleanup materials and contaminated soils should be disposed of properly; the disposal method depending on the composition of the used oil. Incineration or solidification/secure landfilling are the preferred options for disposal of hazardous materials. Sanitary landfilling or land farming are the alternative disposal methods for non-hazardous materials.

Spills on water should be picked up with an oil skimmer and treated to remove excess water. The used oils can then, in most cases, be recycled or reused.

4 HANDLING OF USED OIL

Appropriate procedures and facilities must be developed if used oils are to be handled and collected in a manner which facilitates recycling and reuse. Suitable used oil collection/storage devices must be available to small volume generators to encourage them to dispose of and segregate their oils at local collection centres. Medium to large volume generators must be encouraged to segregate and avoid contamination of oils collected on-site. The following sections describe handling techniques that will provide for the collection of used oils in an environmentally acceptable manner.

4.1 Small Volume Generators

Small volume generators are those who have no, or very limited, on-site used oil storage facilities. The large number of "do-it-yourself" oil changers located in urban areas are included in this category. These generators require containers to collect the oil from a single engine oil change and to transport it to a local collection centre. A combined oil collection/transfer container normally available at automotive supply or hardware stores can be used for this purpose. This container is a 10- to 15-L, high density plastic jerry can with a recessed drain pan built into the side. Alternatively, "do-it-yourselfers" can use a wide pan-type container to collect the oil and then, using a funnel, transfer it to a second container for transport to the local collection centre. This second container can be any heavy duty plastic bottle (e.g., rinsed bleach and windshield wiper fluid bottles) or the container in which the oil was originally purchased (Ontario Waste Management Advisory Board and Environment Canada, 1981).

Small volume generators in rural areas often store used oils in 200-L drums which should be covered, located away from drainageways, and checked regularly for leaks.

Regardless of the methods for handling small volumes of used oil, a public education program is necessary to encourage small volume generators to return their used oil. The thrust of the program should be towards returning the oil rather than disposing of it. Program emphasis should be on oil segregation to inform the public that crankcase oil, hydraulic fluids, paints and solvents are not to be mixed prior to returning them.

4.2 Local Collection Centres

Local collection centres include service stations and automotive retail outlets which make their storage facilities available to the public. The local centres also include municipal collection depots maintained exclusively for used oils. There are two basic approaches that can be used to handle used oils brought to service station and retail outlets. In the first, station staff receive the used oil containers and empty them into a movable drum already used to collect oils drained from vehicles on the premises. This drum is periodically emptied into the station's underground used oil holding tank. These holding tanks typically have capacities ranging from 2300 to 6800 L and are accessed via a lockable opening at grade. This method of used oil handling is convenient for the generator and reduces the potential for spills but involves a significant commitment of time by station staff.

The other approach allows the generators themselves to empty their used oils into a movable drum located outside the service station. Station staff transfer the contents of this drum to the underground used oil storage tank as required. This approach minimizes interruptions of the station's normal operations and can increase used oil recoveries by providing a highly visible collection site. Appropriate collection drums, however, require a significant expenditure by the station's owner, are subject to tipping in high winds and require regular maintenance to clean up spills.

The most appropriate used oil handling approach for a given station will be determined by its physical layout, daily sales volumes, availability of staff and owner preferences. Any of the approaches previously mentioned can be implemented successfully if the station owner and staff are sufficiently committed to the program.

In addition to developing means for handling oils delivered by small volume generators, the service station operators and retail outlets should institute in-house protocols for handling used oils. Recommended procedures include (Ontario Ministry of the Environment, 1986):

- used oils should be stored in a tank designed and used exclusively for that purpose; the tank should not be used for the disposal of non-petroleum products;
- used oil storage tanks should be capped securely at all times;
- service station operators should arrange for an approved used oil carrier to empty the used oil storage tanks as required;
- service station operators should endeavour to prevent used oils from entering sewer systems, drainageways and the natural environment; and
- service station operators should report any used oil spills to the appropriate authorities immediately.

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

- posting a sign stating the used oil products, by brand or generic names, which are accepted for collection;
- erecting an information board or providing information regarding disposal options for used oil products which are not accepted (i.e., names, addresses and phone numbers of local collectors or government agencies involved in special waste collection);
- introducing 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
- erecting a fence with a locked gate around the oil drop-off facility or use drums with locked caps (as used for automotive gas tanks); ensuring that each customer fills out a receipt before the key for access is released.

All of these 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.

Rural areas may not be adequately served by automotive service and retail outlets and may require the establishment of 'stand alone' local collection centres. These centres would consist of an unattended, above or below ground storage tank with a capacity ranging anywhere from 200 to 1500 L, depending on the size of the area serviced and the anticipated collection frequency. Unattended collection centres should be designed and operated considering the following:

- the site must be accessible but located away from drainageways 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 wich 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.

4.3 Industrial/Commercial Generators

Industrial and commercial used oil generators normally have in-house oil storage facilities. As moderate to large used oil generators, they can by-pass the local collection centres and deliver their oils directly to regional transfer stations or recycling or reuse locations. Appropriate used oil handling protocols for industrial and commercial operations are essentially the same as those described for automotive service and retail outlets. Used oils should be stored in dedicated facilities designed and operated to minimize oil contamination and spillage. In addition, industrial and commercial operations should provide separate facilities for each type of used oil generated (i.e., lubricants, hydraulic fluids, metal working fluids, insulating fluids). This will ensure that oils are ultimately directed to the most appropriate reprocessing, recycling, end use or disposal alternative.

4.4 Regional Transfer Stations

Regional used oil transfer stations consist of large (approximately 30 000 to 50 000 L) underground storage tanks used for the collection of oils delivered by local haulers. These facilities are most appropriately located in industrial areas and should be constructed to restrict access to the general public and to limit the discharge of oily runoff from the site. The stations should be inspected regularly for maintenance requirements and tank oil levels. A used oil material balance should be maintained for each station to provide for early detection of leaks. However, secondary leak containment, such as double-walled tanks, is a better method of preventing leaks, although it is more expensive than keeping oil material balances.

4.5 Used Oil Containers

Small quantities of used oil (less than about 20 L) can be stored in virtually any common household container provided it is covered, has no leaks, and has been rinsed of its previous contents. Glass containers, however, should be avoided because of the possibility of breakage.

Above ground used oil drums or tanks should be constructed of steel or plastic in accordance with applicable fire codes. Openings must be located and sized so that 10 to 20 L of oil (at a time) can be easily transferred to the container. If a funnel is required, it should be large enough to avoid overflow and strong enough to support a 20 L used oil container. Drums or tanks should be designed for various weather conditions and should be constructed to facilitate the removal of the oils collected. Unattended containers should be equipped with lockable drain taps that are resistant to vandalism (Ontario Waste Management Advisory Board and Environment Canada, 1981).

Underground storage tanks should be constructed of cathodically-protected steel or fibreglass-reinforced plastic built in accordance with National Standards of Canada (CAN4-S603.1 and CAN4-S615) (pers. comm. Campbell, 1987). The use of a secondary containment system for underground used oil tanks (double-walled tank) is highly recommended because of the difficulty of leak detection. In addition, removable suction tubes (with quickconnect couplings) are recommended by the Canadian Council of Resource and Environment Ministers (CCREM) (pers. comm. Campbell, 1987). Large facilities (transfer station tanks) should be compartmentalized to segregate bottom sediment and water from the oil and equipped with access hatches and sludge removal pipes.

5 RECYCLING, REUSE AND DISPOSAL OF USED OIL

5.1 Introduction

Used oils can be recycled or reused in a variety of ways. The most desirable alternatives conserve the lubricating properties of the oil, utilize its heating value, and add to the reduction of the consumption of virgin oils. The various recycling/reuse options vary in their capabilities to re-utilize oils while minimizing negative environmental effects.

Used oil disposal involves destroying the oil and its contaminants or treating it for safe disposal. Disposal is less desirable than recycling or reuse from an economic and resource conservation point of view. Disposal should be considered only for highly contaminated used oils that cannot be cost-effectively re-utilized.

The following sections describe used oil recycling, reuse and disposal options, and characterize the environmental risks associated with each. Emphasis is given to practices which are recommended on the basis of their resource conservation and environmental benefits.

5.2 Reprocessing and Re-refining

Reprocessing and re-refining involve removing contaminants in used oils so that they are suitable for reuse. These technologies are the most desirable alternatives for the re-utilization of used oils because they conserve its lubricating value and reduce the consumption of virgin oil products. A barrel of refined crude oil produces 1/10 of a barrel of lube oil stock. Consequently, ten barrels of crude oil are conserved for every barrel of re-refined used lube oil produced from used-oil stock.

5.2.1 Reprocessing. In reprocessing, relatively simple physical/chemical treatments such as settling, dehydration, flashing, filtration, coagulation and centrifugation are applied 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, at source, segregation of used oil stocks is essential. Reprocessed oils are used most commonly in industrial applications.

5.2.2 Re-refining. Re-refining technologies are designed to fully restore the original usefulness of the oil. The technological capabilities of the re-refining industry have advanced to the point where most used oils can be recycled successfully; however, some limitations on used oil feedstocks are still required. Oils which can and cannot be re-refined are listed in Table 7.

TABLE 7 USED OILS COMMONLY RE-REFINED BY THE CANADIAN ASSOCIATION OF RE-REFINERS

Re-refinables (complete list)	Non-Re-refinables (partial list)
High Viscosity Index (HVI) Oils All diesel and gasoline crankcase oils	Oils Containing Polychlorinated Biphenyls (PCBs) and Polynuclear Aromatics (PNAs)
Transmission oils	LVI and MVI oils
Hydraulic oils (non-synthetic)	Halides
Gear oils (non-fatty)	Synthetic oils
Transformer oils (non-PCB)	Brake Fluids
Dryer Bearing oils	Fatty oil
Compressor oils	Asphaltic oils
Turbine oils	Black oils
Machine oils (non-fatty)	Bunker oils
Grinding oils (non-fatty)	Metal working oils containing fatty acids
Quenching oils (non-fatty)	Form oils
	Rolling oils
	Solvents of any type

Re-refining Processes. Re-refining typically involves the physical/chemical treatments used for reprocessing followed by other techniques such as demetallization, distillation, stripping, clay contacting, solvent extraction and hydrogenation. The commercially proven re-refining processes commonly used in North America are:

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

A recent technological innovation, film or wiped film evaporators, has made vacuum distillation a very successful refining process.

Canadian re-refiners and the processes they use are identified in Table 8. The following sections provide a brief description of these processes.

TABLE 8 DESCRIPTION OF RE-REFINERS IN CANADA (from Fisher, 1986)

Re-refiner	Province	City	Plant Capacity (10^6 L/yr)	Throughput Feed-1986 (10^6 L/yr)	Type of Process
Mohawk	B.C.	N. 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	82[b]	Vacuum Distillation/ Clay or Hydrotreating
Oil Canada[c]	Ontario	Toronto	49	32	Phillips/ Shell Hydrotreating
Corundol Oil	Ontario	Rexdale	4.5	N/A	Vacuum Distillation/ Clay
Total	-	-	224.5	149[d]	-

a summer operation only
b of the 82 million litres of used oil re-refined in 1986, 40% was from Canada and 60% was from the United States
c former name: Canadian Oil
d 100 x 10^6 L of Canadian throughput feed (see footnote b)

a) Acid/Clay Process. The acid/clay process is the oldest and most common re-refining technology. It involves the reaction of used oil and sulphuric acid to dissolve or settle metal salts and 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.

b) Vacuum Distillation/Clay Process. To recover the oil basestock from used oil, vacuum distillation is implemented, followed by treatment with clay to remove any remaining colour. Distillation bottoms generated by the process may be blended with fuel oil to form high ash fuel oil. Varying grades of oil may be produced through this process allowing the re-refiner added flexibility in blending to meet different product specifications.

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

d) 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 PROP process can produce a great variety of re-refined oils.

Re-refining Products and By-products. All re-refining facilities produce a re-refined 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 value 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 that are directed to treatment and/or disposal.

The 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, the basestocks produced from the vacuum distillation processes are of better quality 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%.

Re-refining By-product Waste Handling. The disposition of contaminants in used oil when re-refined by the acid/clay process is shown in Table 9. Acid sludges from 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; therefore, landfilling has traditionally been the most common method of disposal. The high acid and lead content of this sludge, however, generates environmental concerns which are difficult to control in conventional sanitary landfills. Alternative treatment/disposal measures such as lime neutralization or shipment to special waste disposal facilities should be considered for these sludges.

Spent clay is generated in all re-refining processes except vacuum distillation/hydrotreating. It normally contains high oil levels and colour generating organics, but is typically less contaminated than acid sludge and therefore more amenable to disposal by landfilling. Centrifuge sludge is generated in vacuum distillation processes. This sludge often contains caustic, sodium silicate, lead, oil and other materials. Appropriate disposal options should be established from site specific centrifuge sludge characterizations.

Process wastewaters include water decanted or flashed from the used oil feed, 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.

The disposition of contaminants in used oil when re-refined by the vacuum distillation/hydrofinishing process is shown in Table 10. Most of the metals are concentrated in the residue which contains few organic contaminants. The organic contaminants tend to split between the distillate and hydrotreated product.

Comparison of Re-refining Alternatives. The three most common re-refining technologies with respect to product yield, utility and energy requirements, hazardous chemicals used and waste volumes produced are qualitatively compared in Table 11. From an environmental perspective, re-refining processes can be ranked according to the effects of these waste streams on the environment. Table 12 provides such a ranking of re-refining waste streams.

TABLE 9 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	1250	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 phthalate	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

TABLE 10 DISPOSITION OF CONTAMINANTS IN PROCESS AND WASTE STREAMS DURING LABORATORY SIMULATIONS OF A VACUUM DISTILLATION/HYDROFINISHING RE-REFINING PROCESS (from Surprenant et al., 1983)

Parameter	Feedstock	Distillate	Distillate Residue	Hydro-treated 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	1250	0.8	1150	< 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
* ND - not detected at concentrations above 10 µg/g
** ND - not detected at concentrations above 20 µg/g

TABLE 11 COMPARISON OF RE-REFINING TECHNOLOGIES (from Rudolph, 1978)

Evaluation Item	Acid/Clay	Vacuum Distillation/ Clay	Vacuum Distillation/ Hydrotreating
1. Lube yield[a]	Low	Medium	Medium
2. Bright stocks[b]	Recovered	Lost	Lost
3. Utilities[c]	Low	Low	High
4. Overall energy[d]	High	Low	Medium
5. Hazardous chemicals[e]	Sulphuric Acid	Caustic	Caustic
<u>Waste Streams</u>			
6. Acid sludge	Most	None	None
7. Oily clay	Most	Some	None
8. Caustic sludge or spent caustic	None	Some	Some
9. Process water	Low	Medium	High

a <u>Lube yield</u>. The oil yield in the acid/clay process is low because of losses to the acid sludge. The two distillation processes do not recover bright stocks and this is reflected in their moderate lube oil recovery.

b <u>Bright stocks</u>. Bright stocks are recovered only in the acid/clay process. This process would be favoured in the unusual situation where used oils contain extremely high proportions of bright stocks.

c <u>Utilities</u>. 'Utilities' refers to the total external energy requirement (power plus fuel).

d <u>Overall energy</u>. This is total external energy (utilities) plus potential energy lost in non-recovered oils.

e <u>Hazardous chemicals</u>. In the acid/clay process, the operators are exposed to the risk of handling sulphuric acid and the resulting acid sludge. All three processes expose the operators to possible chemical burns.

TABLE 12 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 and lead content
Caustic sludge	2	Sodium hydroxide and lead content
Sulphur dioxide emissions	3	Known biotic effects
High ash residue	4	Lead content
Spent clay	5	N/A
Process wastewater	6	N/A
Propane and hydrogen emissions	7	N/A

* 1 - most hazardous
N/A - not available

Information from Tables 11 and 12 suggests 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 produced acid sludge which creates a difficult disposal problem. The spent oily clay is also produced in large quantities; however, its disposal is less problematic.

Recommended Re-refining Processes. Re-refiners should be encouraged to construct new facilities using vacuum distillation processes (distillation/hydrotreating, distillation/clay) rather than the acid/clay treatment process because of the re-refiners low rates of produced wastes.

5.3 Burning

Virtually any burner designed for No. 6 fuel oil and most burners designed for No. 4 and No. 5 oils can burn untreated used oil, although some equipment modifications may be required for systems designed for the lighter fuels (PEDCo-Environmental Inc., 1984). Used oil can be burned (Franklin Associates Ltd., 1985; Proctor and Redfern Ltd. et al., 1984) in: various boiler types and sizes; cement and brick kilns; small oil space heaters; asphalt plants; and diesel engines.

Used oil burning utilizes the oil's heating value and reduces the consumption of non-renewable fossil fuels but can create significant environmental concerns with respect to the release of heavy metals and toxic organics to the atmosphere. The extent of these concerns varies depending on:

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

As mentioned previously, the Province of Quebec has issued guidelines specifying permissible maximum contaminants levels in used oil which may be burned, while the Province of Ontario is presently developing a specification for waste derived fuel. Nevertheless, federal and provincial guidelines for permissible source emissions of air contaminants due to used oil burning are yet to be developed. The Canadian Council of Resource and Environment Ministers (CCREM) is presently developing source emission regulations for municipal solid waste incinerators (pers. comm. Campbell, 1987). The base emission data from which emission limits will be recommended to CCREM are summarized in Table 13. 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 Canadian emission limits in the third table column were announced by CCREM and have been adopted for emissions from used oil burning (pers. comm. Campbell, 1987).

The environmental effects of used oil burning in various types of burners are described in the following subsections.

5.3.1 Boilers. Most oil-fired domestic, commercial, industrial or utility boilers can burn used oil. However, it is most readily used 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 as they do not have the potential for tube and furnace fouling associated with the latter.

Studies of flue gases from small commercial boilers (400 000 to 15 800 000 kJ/h) fuelled with straight used oil have generally shown that atmospheric emissions of potentially harmful inorganic compounds, particularly lead and hydrogen chloride, are quantitatively more significant than organic emissions (GCA Corporation, 1984; PEDCo - Environmental Inc., 1984). The concentrations of heavy metals in the flue gases of small commercial boilers fuelled with used oil are summarized in Table 14. A

TABLE 13 BASIS FOR SOURCE EMISSION LIMITS FOR MUNICIPAL SOLID WASTE INCINERATORS RECOMMENDED TO THE CANADIAN COUNCIL OF RESOURCE AND ENVIRONMENT MINISTERS (CCREM)*

Parameter	Capability of 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 $\mu g/m^3$
Lead (Pb)	1 to 25 mg/Nm^3	3 to 5.3 mg/Nm^3	50 $\mu g/m^3$
Chromium (Cr)	0.6 to 6 mg/Nm^3	0.8 to 5.3 mg/Nm^3	10 $\mu g/m^3$
Mercury (Hg)	100 to 610 mg/Nm^3	0.2 to 0.8 mg/Nm^3	200 $\mu g/m^3$
Arsenic (As)	0.007 to 0.33 mg/Nm^3	0.8 to 0.9 mg/Nm^3	1 $\mu g/m^3$
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 $\mu g/m^3$
Polychlorinated Biphenyls (PCBs)	0 to 9 ng/Nm^3		1 mg/kg PCB input
Chlorobenzene (CB)	80 to 2900 ng/Nm^3		1 $\mu g/m^3$
Chlorophenol (CP)	250 to 8400 ng/Nm^3		1 $\mu g/m^3$

* 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.

*** Sum of the 2,3,7,8 substituted PCDDs and PCDFs derived from congener specific analytical data using the Nato/CCMS toxicity equivalent factors.

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

ng = nanogram (1ng = 10^{-9} grams)

TABLE 14 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	17 981
Lead	9680	72 400	5390	20 300	49 800	51 000	34 762

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

comparison of the values listed in this table and the metal concentration limit data listed in Table 13 shows that the limit data are exceeded for emissions of lead, chromium, arsenic and, in some cases, the limits are exceeded for emissions of cadmium.

Destruction removal efficiencies for organic compounds in used oil fuels, which are burned in small boilers, are reported to be in the 99.4 to 99.9% range. Residual concentrations of these compounds have been determined to pose a measurable health risk (PEDCo-Environmental Inc., 1984). The results of a risk analysis for emissions generated during the burning of used oils in boilers with capacities lower than about 25×10^6 kJ/h are shown in Table 15.

Large industrial and utility boilers are generally considered to pose relatively low 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 that 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

TABLE 15 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

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 quantities 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 that would generate potentially harmful emissions when burned;
- pollution control devices; a relatively high 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 high stacks that increase the dispersion of contaminants and improve ground level ambient air quality; and
- location; industrial and utility boilers are generally not 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 fuels;
- installation of flue gas emission control equipment; and/or
- implementation of a program to incorporate various combinations of the above options.

5.3.2 **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 which are ground and blended with calcium sulphate to produce Portland cement. Kilns normally burn No. 6 fuel oil, natural gas, or coal and can be easily modified to burn used oil which has been 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 used oil in small- to medium-sized boilers. By their very nature, kilns exhibit a gas scrubbing action that 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 cement would not be compromised by burning used oil fuels and that most of the oil contaminants would remain within the insoluble structure of the hydrated compounds in concrete (Berry and Macdonald, 1975).

5.3.3 Other Burners. Space heaters, asphalt plants, diesel engines and even coal-fired utility boilers can burn used oils to satisfy at least a portion of their fuel requirements. Unless equipped with burners of high combustion and contaminant destruction efficiencies or with flue gas treatment devices, used oil burning in most of these facilities should be discouraged. Unacceptably high contaminant concentrations in flue gases and/or solid residuals usually result from uncontrolled burning of used oil. Some applications (burning in coal-fired utility boilers) may be acceptable in some circumstances; however, burning proposals should be evaluated on a site specific basis.

5.3.4 Recommended Burning Practices. The following controlled burning practices are appropriate for used oils. 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 oil fuels meet specified standards for maximum contaminant levels and minimum heating values.

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 Other Reuse Practices

Used oils have traditionally been directed to a variety of uses other than re-refining and burning. These alternatives include uses such as (Franklin Associates Ltd., 1985; and King, 1980):

- road oil;
- raw material in asphalt production;
- flotation and form oil;
- secondary lubricant;
- pesticide carrier;
- weed killer;
- livestock oil;
- all-purpose cleaner; and
- vehicle undercoating.

The uses of road oiling and asphalt production are discussed separately in the following, while the other uses are discussed collectively.

5.4.1 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 which have a high proportion of unpaved roads and are located some distance from other used oil markets (burning and re-refining). While some road oiling is 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 (re-refining), availability of alternative dust suppression substitutes (calcium chloride, 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).

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 may contaminate soil 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.

Freestone (1972) in a U.S. EPA study suggested that only about one percent of the oil applied actually remains on 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 that 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 below the average for urban soils in Ontario; and
- the U.S. EPA findings applied only to the road section and used oil evaluated; the findings 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 1000 ppm. At lower depths, oil could not be detected. The ultimate distribution of used oil applied to the road surface is summarized in Table 16.

Analysis 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 that was entrained and carried from the road surface. The water soluble component of road oil was

TABLE 16 DISPOSITION OF OIL FOLLOWING APPLICATION TO TEST ROADBED SURFACES (from Surprenant et al., 1983)

	Percent of Total Oil Applied	
Fate of Used Oil	Roadbed Soil	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 on the road surface is eventually lost through adhesion to vehicles, biodegradation, and wind entrainment of dust particles

determined to be very small. The concentrations of inorganic and organic road oil constituents in the runoff are summarized in Tables 17 and 18. The only constituent of obvious concern was phenol whose concentration appeared to be above recommended environmental goals (approximately 5 µg/L). Interpretation of this data was difficult because the time variation of contaminant concentrations was not established and because of the possible influence of external 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 impact of road oiling is not overly severe. They recommended that additional work be undertaken to more fully characterize potential effects under worst case conditions.

These studies do not conclusively define all the environmental concerns which may be generated by road oiling. Nevertheless, researchers do suggest that the potential effects are severe enough to warrant the discouraging of road oiling wherever possible.

5.4.2 **Asphalt Production.** Used oils have been used occasionally 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

TABLE 17 ELEMENTAL 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

TABLE 18 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

incorporated into the final product. Leaching of significant contaminant concentrations from finished asphalt roads and roofs is considered unlikely; however, the potential effects of using waste oils in asphalt production should be evaluated on a site or region specific basis.

5.4.3 Miscellaneous End Uses. The environmental effects associated with the other end uses listed earlier vary from one application to another. The nature and extent of concerns for any given application will 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. Generally speaking, these practices should be avoided unless it can be demonstrated that environmental risks can be effectively controlled on a site-specific basis.

5.4.4 Recommended Practices for Other Reuses. None of the reuse practices previously described are specifically recommended due to the identified lack of data regarding their environmental effects.

Road oiling should be discouraged in jurisdictions where alternative and better reuse practices (re-refining and controlled burning) are available. Road oiling, however, should be considered as a best available reuse practice in remote and rural areas where the reuse options of re-refining and controlled burning, as well as acceptable disposal practices, are not available.

The other reuses of used oil, including asphalt production, should be reviewed on a case specific basis regarding their environmental effects before they are implemented.

5.5 Disposal

Used oil disposal involves the use of facilities or repositories which do not utilize the oil's lubricating and/or heating value. Recommended disposal options for used oil are: burning in a hazardous waste incinerator; and solidification followed by disposal in a secure landfill.

These disposal options as well as other disposal practices (landfarming, disposal to sewers and indiscriminate dumping) are summarized in the following subsections.

5.5.1 Incineration. Hazardous waste incinerators use high temperatures under controlled 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 basic operating principles of these technologies are summarized in Table 19. 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 can 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

TABLE 19 SUMMARY OF COMMONLY USED INCINERATION TECHNOLOGIES (from U.S. EPA, 1985)

Type	Process Principle	Combustion Temperature (°C)	Residence Time
Rotary Kiln	- waste is burned in a rotating refractory cylinder	800 to 1700	- seconds for gases to hours for liquids and solids
Single Chamber/ Liquid Injection	- wastes are atomized with high pressure air or steam and burned in suspension	700 to 1700	- 0.1 to 1 second
Multiple Hearth	- wastes descend through several grates to be burned in increasingly hotter combustion zones	750 to 1000	- up to several hours
Fluidized-Bed	- waste is injected into an agitated bed of heated inert particles; heat is effficiently transferred to the wastes during combustion	750 to 900	- seconds for gases and liquids, minutes for solids

oil's heating value is used to reduce virgin fuel consumption. From an environmental perspective, this end use would be desirable as contaminated flue gas emissions and solid residuals are effectively controlled.

5.5.2 Landfilling. The only environmentally acceptable way to landfill used oils is to mix them with sorbent materials before depositing the solidified mass in an authorized hazardous waste landfill. An authorized hazardous waste landfill is a facility constructed with leachate collection/treatment systems and impervious liners in an area which has favourable soil and groundwater conditions (impervious soils with high buffering capacities and a low groundwater table).

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 disposal of used oils in conventional sanitary landfills should be actively discouraged. These landfills typically do not incorporate the features necessary to contain used oil contaminants and, in many cases, are not 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.

Landfilling of used oil may be regulated in the near future unless the oil is pretreated by best available control technology or it meets certain criteria (pers. comm. Campbell, 1987). Criteria (recommended by a federal-provincial task force on hazardous waste landfilling) which will prohibit the landfilling of used oil are:

- it is a liquid waste or it exists as a free liquid within a solid waste;
- it contains more than 1 wt. % of liquid Total Organic Carbon;
- it is flammable;
- it contains more than 0.1 wt. % of halogenated organic carbon wastes; and
- it is not diluted prior to landfilling.

If implemented for used oils in provincial and territorial jurisdictions, these criteria will prevent the landfilling of used oil unless they are solidified or pretreated to meet these criteria prior to disposal.

5.5.3 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 under the right conditions, used oils can be degraded by land application, 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 that 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 Canadian 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 one weight percent oil-in-soil content as a rule of thumb. A three weight percent content is considered an absolute maximum. These numbers are based on a 15-cm depth of soil covering a one hectare plot of land; the volume of which weighs 2×10^6 kg. The WTC also suggests that oils containing aromatic hydrocarbons be given special consideration as aromatic compounds tend to degrade much slower than other oil compounds when landfarming oils.

5.5.4 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 shown in Table 20. These levels

TABLE 20 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)	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

show that the discharge of used oils to sewer systems should not prove harmful to most municipal treatment works and that many of the potentially significant contaminants (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 20 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 storm water control is not practiced and to other populations downstream of storm water discharge points.

5.5.5 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.

5.5.6 Recommended Disposal Practices. Used oils should be disposed of by burning in a hazardous waste incinerator or by solidification followed by disposal in an authorized hazardous waste landfill. Disposal of used oils by landfarming, sewer discharge and indiscriminate dumping should not be considered as these options do not provide adequate control of environmental risks.

6 GUIDELINES FOR THE DEVELOPMENT OF USED OIL MANAGEMENT STRATEGIES

6.1 Introduction

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

6.2 Used Oil Collection and Marketing

Collectively funded and operated used oil collection systems will be required if a large proportion of the used oils generated in a province or region are to be recovered. The used oil available for recycling in large centres (from service stations and industries) is by and large collected and reused. The provincial and territorial collection systems will need to focus on three important areas of used oil generation:

- rural areas;
- northern regions; and
- "do-it-yourself" oil changers.

In addition to providing the environmental and resource conservation benefits associated with high used oil recoveries, the collection systems will assist marketing efforts by providing a reliable source of used oil.

The importance of marketing for used oils and used oil products cannot be underestimated. High used oil recoveries can be sustained only if environmentally acceptable recycling and end use markets are established for the oils collected.

The education campaign described in the following is primarily directed towards "do-it-yourself" oil changers.

Used oil collection and marketing efforts should be supported by an ongoing public education campaign designed to:

- heighten awareness of the benefits of recycling and the environmental implications of improper reuse or disposal;
- highlight the cost advantages of using recycled as opposed to virgin oil products;
- show consumers that the quality of re-refined products is comparable to that of virgin oils;

- encourage the provision of labels on virgin oil products advising consumers to deliver used oils to appropriate collection centres;
- notify the public of the existence of local collection centres and provide advice on delivery procedures;
- encourage retail outlets to display used oil collectors/containers prominently (preferably adjacent to bulk virgin oil containers); and
- advise the public of contaminants that should not be added to used oil supplies (water, anti-freeze, solids, solvents, gasoline).

6.3 Used Oil Recycling and Reuse

Used oils collected must be directed to appropriate recyclers or users if environmental and resource conservation benefits are to be maximized. Recommended practices in order of preference are:

- re-refining and reprocessing;
- burning in cement kilns;
- burning in industrial and utility boilers equipped with flue gas pollution control equipment; and
- burning in boilers not equipped with flue gas pollution control equipment when used oil fuels meet specified standards for maximum contaminant levels and minimum heating values.

Road oiling or uncontrolled burning is not a recommended practice unless it can be demonstrated under particular circumstances (rural areas and northern regions) that this practice is the best available control technology, defined as the technology providing the most benefit to the area at the least expense to the environment.

Re-refiners should be encouraged to construct new facilities using vacuum distillation processes (vacuum distillation/hydrotreating, distillation/clay, demetalization/ vacuum/distillation/hydrotreating) rather than an acid/clay treatment process to improve the economic viability of re-refining and to minimize its environmental impact.

The number of used oil burners (particularly those without emission control equipment) in a given area should be limited to maintain ambient air quality standards. Regulations should be promulgated to ensure that contaminated solid residuals generated during used oil burning are disposed of in an environmentally acceptable manner.

Used oil management strategies should incorporate disincentives for environmentally inappropriate end use practices. The extent of these limitations for a given area should be determined in part by the scope of local collection facilities. In areas which are served adequately 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 available collection services. For areas in which these services cannot be provided (rural areas and northern regons), bans on road oiling and uncontrolled burning should be carefully evaluated. Bans in such areas may accomplish little more than the redirection of used oils to even more objectionable end uses such as uncontrolled landfilling and indiscriminate dumping.

6.4 Used Oil Disposal

The disposal of used oils should be discouraged in favour of recycling and controlled burning. Highly contaminated oils that 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. Used oil disposal by dumping into sewer systems and conventional sanitary landfills and indiscriminate land dumping should be prohibited.

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