

5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

Used mineral-based crankcase oil is a complex mixture of low and high (C_{15} - C_{50}) molecular weight aliphatic and aromatic hydrocarbons, lubrication additives, metals, and various organic and inorganic compounds. The chemical composition of used mineral-based crankcase oil varies widely and depends on the original crude oil, the processes used during refining, the efficiency and type of engine the oil is lubricating, the gasoline combustion products, the additives added to the fuel and to the original oil, and the length of time that the oil remains in the engine. The oil is typically 73-80% weight/weight aliphatic hydrocarbons (primarily alkanes and cycloalkanes with 1-6 rings); 11-15% monoaromatic hydrocarbons; 2-5% diaromatic hydrocarbons; and 4-8% polyaromatic hydrocarbons (Vasquez-Duhalt 1989). The lubrication additives, which are approximately 20% of the oil, consist primarily of zinc diaryl, molybdenum disulfide, zinc dithiophosphate, metal soaps, and other organometallic compounds. Detergents and dispersants constitute 2-15% of the additives (Vasquez-Duhalt 1989).

Other compounds found in used mineral-based crankcase oil as a result of oil additives include barium, phosphorus, zinc, and some chlorine and bromine compounds (Vermont Agency of Natural Resources 1994). Average metal concentrations found in used gasoline engine oil in a 1994 study are barium at 2.73 ppm, beryllium at <0.02 ppm, cadmium at <1.51 ppm, chromium at 3.19 ppm, lead at 47.23 ppm, nickel at <1.40 ppm, and zinc at 1,161 ppm (Vermont Agency of Natural Resources 1994). Levels of barium have decreased dramatically in recent years because barium is no longer is a component in lubricant dispersants. However, zinc concentrations have remained steady because of its use in lubricant detergents (Entropy 1994). Generally, metal levels in automotive-generated oils are higher than the levels found in industrial-generated oils (Mueller Associates 1987). The highest concentrations of metal levels are found in the combustion effluents of automotive-generated used oils rather than in truck-generated oils (Hall et al. 1983a). Prior to the introduction of unleaded gasoline, lead levels in used mineral-based crankcase oil were approximately 13,000 $\mu\text{g/g}$ (Vasquez-Duhalt 1989). In 1983, used oil lead levels had dropped to an average of 1,100 ppm for the 24 samples of used oil tested (Suprenant et al. 1983). In a 1994 study, a lead level of 47.23 ppm was found in used gasoline engine oil (Vermont Agency of Natural Resources 1994). Lead content in used mineral-based

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crankcase oil is predominantly a result of piston blow-by of the combustion products of leaded gasoline (Mueller Associates 1987; Vermont Agency of Natural Resources 1994).

Additional organic and inorganic compounds found in used mineral-based crankcase oil are sulfur, aluminum, arsenic, calcium, chromium, copper, iron, magnesium, manganese, potassium, silicon, sodium, tin, toluene, benzene, xylene, ethylbenzene, and nitrogen, although most organic compounds are destroyed during combustion of used mineral-based crankcase oil as fuel (Canadian Environmental Protection Agency 1994; Vermont Agency of Natural Resources 1994). The toxicity of chromium is dependent upon its structural form, as it exists in eight different oxidation states. The most stable forms are the trivalent and hexavalent forms, with the hexavalent form being the most toxic of the various states (Vermont Agency of Natural Resources 1994).

Small amounts of PCBs were in the past incorporated into transmission fluids to control swelling of rubber seals (Mueller Associates 1987). PCBs were also detected in 4 of 24 used oil samples at concentrations of 7, 13, 18, and 65 ppm (Suprenant 1983). It should be noted that PCBs have never been used in lubricant additives or in the creation of new motor oils. Because dioxins can form from PCBs, which has severe health implications, production of PCBs for commercial purposes has almost ceased (Hewstone 1994b). The 24 samples in the Suprenant et al. (1983) study also contained an average concentration of 20 ppm of benz(a)anthracene with benzo(a)pyrene below the detection limit of 5 ppm. Both of these polynuclear aromatics (PNAs) are considered hazardous and carcinogenic to humans (Suprenant 1983).

Used mineral-based crankcase oil may be released directly into the air, water, or soil through fuel burning, re-refining, engine oil leaks, automobile or truck exhaust, uncontrolled disposal into sewers or landfills, and to a lesser extent via environmental spills. Used mineral-based crankcase oil can also be released into the environment as a dust suppressant on rural roads (Canadian Environmental Protection Act 1994). However, in most states strict regulations now prohibit or limit the use of used oil as a dust suppressant (Mueller Associates 1987). In addition, metal particulates may be released into the atmosphere, depending upon their volatility, through engine exhaust or when used mineral-based crankcase oil is used as supplemental fuel in boilers and incinerators.

In 1983, approximately 699 million gallons of automotive used oil were created. The primary sources of this oil were do-it-yourself oil changers, which accounted for 34.2% of all automotive oil generated.

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Sources such as service stations and repair shops accounted for approximately 214.8 million gallons of used automotive oils. The total used oil, including industrial and automotive oils, consisted of 1.2 billion gallons in 1983. Burning was the primary use of used oils, consuming 48.9% or 590.1 million gallons of the total used oil generated in 1983 (Mueller Associates 1987).

The environmental fate of used mineral-based crankcase oil is dependent on its individual components. See other ATSDR profiles for the environmental fate of specific components such as PAHs, lead, cadmium, and zinc (ATSDR 1990c, 1993b, 1992d, 1989b). Chemical and biological processes such as microbial degradation and oxidation that normally degrade hydrocarbons are less effective on used mineral-based crankcase oil because the high molecular weight hydrocarbons and less-soluble aromatics are less susceptible to these environmental processes. Most high molecular weight hydrocarbons will sorb to organic matter in the soil or particulates in the water column and will eventually accumulate in the sediment. Microbial degradation is dependent on the hydrocarbon fractions present in the used mineral-based crankcase oil, the number of microorganisms present in the soil, sediment, or water, and the environmental conditions, for example, temperature. During microbial degradation, metals may be released from the oil phase into the aqueous phase, which increases the persistence, mobility, and toxicity of the metals. Heavy metals may then accumulate in plants, soil, sediments, surface water, and groundwater.

Minimal exposure to the general population may occur when an individual adds engine oil or checks the engine oil level in a vehicle. Dermal exposure appears to be the primary route of occupational exposure for individuals employed in the automotive industry and for individuals who change their oil or otherwise handle engine components contaminated with used mineral-based crankcase oil. However, non-occupational exposure is expected to occur only a few days per year. Other populations potentially exposed either dermally or by inhalation to used mineral-based crankcase oil include individuals living or working in the vicinity of service stations that improperly dispose of used mineral-based crankcase oil, active or inactive oil recycling or re-refining facilities, or roads that are treated with used mineral-based crankcase oil for dust suppression. Individuals who live & work near facilities that burn used mineral-based crankcase oil as a supplemental fuel for boilers or waste disposal incinerators may be exposed to high levels of metal particulates.

Used mineral-based crankcase oil has been found in at least 85 of the 1,430 current or former EPA National Priorities List (NPL) hazardous waste sites (HAZDAT 1996). However, the number of sites

evaluated for used mineral-based crankcase oil is not known. Of these sites, all 85 are located in the United States, and none are located in the Commonwealth of Puerto Rico.

The frequency of these sites within the United States can be seen in Figure 5-1.

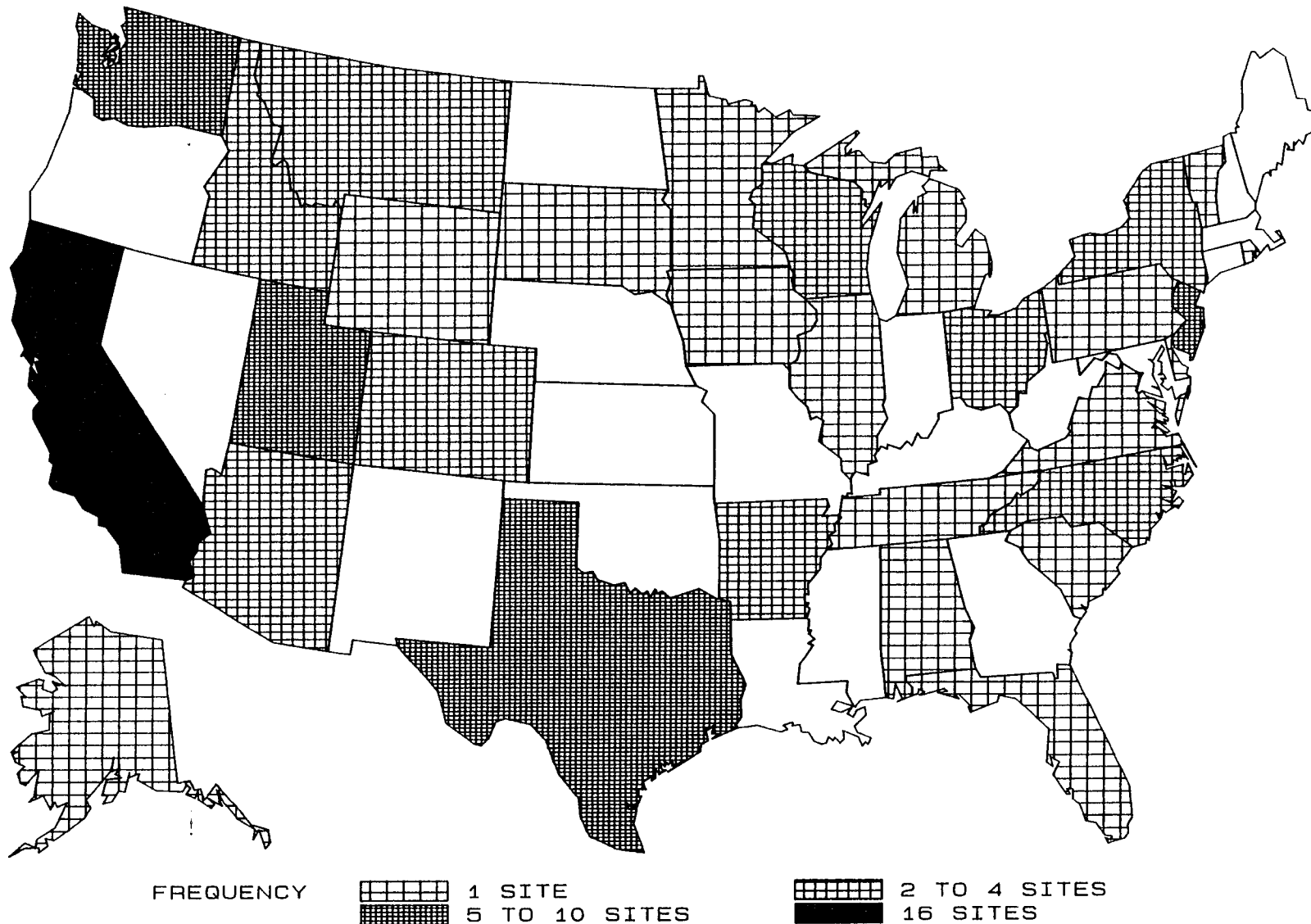
5.2 RELEASES TO THE ENVIRONMENT

Releases of used mineral-based crankcase oil are not required to be reported under SARA Section 313. Consequently, there are no data for this compound in the 1993 Toxics Release Inventory (TRI) (TR193 1995).

5.2.1 Air

The combustion products of used mineral-based crankcase oil may be released to the atmosphere when the oil is used as primary or supplemental fuel in industrial steam boilers, domestic oil burners, utility steam boilers, rotary cement kilns, or waste disposal incinerators. Combustion products of used mineral-based crankcase oil include lead, zinc, chromium, aluminum, nickel, copper, other metal particles, sulfur, nitro-compounds, sulfur dioxide, phosphorus, calcium, hydrochloric acid, and nitrogen oxides (AEC 1974; Canadian Environmental Protection Act 1994; Vasquez-Duhalt 1989). These products may also be released during soot blowing at large boilers or during the cleaning of furnaces or boilers (Mueller Associates 1987). Due to the release of these combustion products, used fuel oil is regulated by its contaminant concentrations and physical characteristics. Used fuel oil which exceeds these maximum concentrations is considered off-specification and is subject to additional regulations regarding the combustion processes (Entropy 1994). According to Entropy (1994), industrial consumers of used oil burn a combined total of 800 million gallons per year for fuel and release 28.06 tons of lead emissions per year including vapor and uncollected particles. It is used in space heaters, commercial boilers, industrial boilers, marine boilers, utility boilers, asphalt plants, cement plants, and pulp-mills. Asphalt plants consume the largest amounts of used oil per year-at 313.4 million gallons, with total lead emissions per year of 9.52 tons. Industrial and utility boilers are the second and third largest consumers of used oil with estimates of 101.4 million gallons and 92.3 million gallons burned per year respectively. Particulate collection efficiency for the different types ranged from 0% efficiency to 95% efficiency for cement plants and steel mills (Entropy 1994). Lead removal efficiency in large boilers >25x10⁶ Btu/hr averages around 70% as a result of destruction

FIGURE 5-1. FREQUENCY OF NPL SITES WITH USED MINERAL-BASED CRANKCASE OIL CONTAMINATION *



*Derived from HazDat 1995

during combustion. Small boilers emit approximately <50% of the lead in the fuel as emissions (Suprenant et al. 1983). A 1983 study reported 590.1 million gallons of used oil was disposed of by incineration (Mueller Associates 1987).

Prior to the introduction of unleaded gasoline, the combustion of used mineral-based crankcase oil in power plants resulted in high levels of lead emissions ($5.0 \mu\text{g}/\text{m}^3$) for 24-hour periods. The combustion of used mineral-based crankcase oil originating from automobile engines, collected from service stations, released $20.9 \mu\text{g}/\text{m}^3$ respirable particulates despite the use of an electrostatic precipitator. No recent data are available for lead emissions from similar combustion sources (Cooper 1977; Mumford et al. 1986). Oil from crankcase-lubricated engines may also be emitted directly with automobile exhaust at concentrations of 0.1-0.25 L/1,000 km or together with particulate emissions in exhaust (Van Donkelaar 1990). Releases of nitrosamines (animal carcinogens and possible human carcinogens) from heavy duty diesel crankcase emissions were reported when using fresh oil. The amount of nitrosamines released is dependant on the type of oil used and the flow rate of NO_x in the crankcase. Limited evidence exists for a decrease in nitrosamine release as the age of the oil increases. Other sources are automobile interiors and possibly diesel exhaust (Baines 1981). Vapors from the application of used mineral-based crankcase oil to rural roads for dust suppression may also be released to the atmosphere.

5.2.2 Water

Releases of used mineral-based crankcase oil in urban stormwater runoff have been reported. Used mineral-based crankcase oil from engine leaks accumulates on parking lots, in garages, and in the central area of roadway lanes. Stormwater runoff from heavily traveled roadways and bridges is often contaminated with used mineral-based crankcase oil, with aliphatic hydrocarbon concentrations ranging from 0.20 to 24 mg/L (200-24,000 $\mu\text{g}/\text{L}$) (Hunter et al. 1979; MacKenzie and Hunter 1979; Van Donkelaar 1990; Wakeham 1977). The contaminated runoff generally enters a sanitary, storm, or combined sewer system and may bypass treatment facilities during periods of heavy rainfall (Tanacredi 1977). When more communities separate storm sewers and sanitary sewers, stormwater treatment plants may be able to remove a portion of the used mineral-based crankcase oil from the stormwater. Direct dumping of used mineral-based crankcase oil into storm drains is a result of motorists changing their own engine oil and not having a convenient collection facility available for disposal. An estimated 7 million gallons out of 340 million gallons of oil drained from automobiles per year are

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dumped into sewers (Suprenant et al. 1983). Contaminated water ultimately reaches streams, rivers, lakes, and sediments because most of the associated hydrocarbons and metals are resistant to traditional waste water treatment methods (Falahi-Ardakani 1984; Farrington and Quinn 1973; Freestone 1979; Hunter et al. 1979; Latimer et al. 1990; MacKenzie and Hunter 1979; Tanacredi 1977; Van Donkelaar 1990; Wakeham 1977).

Hydrocarbons sampled from urban runoff at commercial, residential, and interstate highway sites displayed the same chromatographic characteristics and PAH distribution as used mineral-based crankcase oil. Stormwater runoff from an industrial site in Rhode Island used by oil distributors, scrap metal dealers, and metal finishers contained primarily hydrocarbons (96%) associated with used mineral-based crankcase oil (Latimer et al. 1990). Runoff from roads treated for dust suppression has been hypothesized as a major mechanism of transport for oil leaving the road surface from the months of September through June on a road sampled in New Jersey. Soil samples taken at the base of a drain pipe carrying water away from the treated road showed a lead concentration of 87 mg/kg. A stream receiving runoff from the treated road showed two oil patches which, when analyzed, contained hydrocarbons similar to those found in waste crankcase oil (Freestone 1972). From the data, it is clear that hydrocarbons and heavy metals from used mineral-based crankcase oil are distributed widely in the environment, especially where industrial activity and motor vehicles are found, or where used oil is incinerated, otherwise utilized, or dumped. Surface water, especially runoff from roads, streets, bridges, and sediments in streams and lakes, contains considerable amounts of these materials. Hence, the potential risk to human health and to the environment is significant.

5.2.3 Soil

In 1983, an estimated 50-80 million gallons of used oil was used as a dust suppressant for dirt roads in the United States. At the time of this estimate, road oiling was banned in 8 states and regulated in 13 additional states (Suprenant et al. 1983). This oil can be a source of nearby soil and water contamination because of runoff and leaching. The rates of removal are highly variable ranging from 3-5% removal to as high as 99% removal (Canadian Environmental Protection Act 1994; Freestone 1972). The rate of removal varies as a result of the environmental conditions the road is subjected to and the condition and materials of the road itself. Additional removal of used mineral-based crankcase oil is facilitated by other processes such as adhesion to tires and chemical and biological

degradation (Freestone 1972; Raymond et al 1976; Rudolph 1980; Mueller Associates 1987). The majority of the oil does not penetrate the road and remains close to the surface.

A simulation of oil application on a roadbed showed that the oil did not penetrate to depths deeper than 1 cm, with the largest concentration being within the top few millimeters of the soil. Lead concentrations in soil in a drainage ditch near (exact distance not stated) an oil-treated road ranged from 50 to 136 mg/kg. Concentrations of lead in soil samples taken from a wheat field 47.7 meters from the oil-treated road averaged 24 mg/kg, which is higher than expected for the lead background levels near a rural road (Falahi-Ardakani 1984; Freestone 1979). Other chemicals detected in runoff include zinc, aluminum, sodium, calcium, and organic compounds such as phenol and chlorophenol (Canadian Environmental Protection Act 1994). Solid wastes containing metals, chlorinated solvents, PAHs, and other organics that are created during re-refining are often disposed of in landfills or lagoons or incorporated into road building materials (Mueller Associates 1987; Weinstein et al. 1982). Lead levels in soil near a waste oil re-refinery in Oklahoma City, Oklahoma, which is on the NPL, have been measured as high as 4,810 mg/kg (ATSDR 1990a).

5.3 ENVIRONMENTAL FATE

5.3.1 Transport and Partitioning

Used mineral-based crankcase oil is a complex mixture of aliphatic and aromatic hydrocarbons, metals, and other additives. Upon release to the environment, used mineral-based crankcase oil is not transported as a mixture, but rather, the various components partition to the atmosphere, water, or soil according to their different physical and chemical properties. Therefore, a mixture of used mineral-based crankcase oil is unlikely to be found intact in various media. However, small and moderate spills on soil may remain entrained in the soil near or on the surface. The partitioning behavior of metals is dependent on the form that the metals are in when released into the environment (DOE 1989). Metals released during combustion transform and partition into four different forms: solids that remain in the combustion process, flyash, solid phase product streams, and vapor phase materials (Entropy 1994). The fate of the oil that is directly released to the soil is determined by the nature and the organic content of the soil. Soils with high organic content will tend to absorb the oil and prevent its spread downward as opposed to permeable soil with little organic matter, which will allow the oil to migrate downward and possibly contaminate groundwater supplies (Raymond et al. 1976).

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The majority of the hydrocarbons in used mineral-based crankcase oil are of high molecular weight and will volatilize more slowly because of low estimated vapor pressures (<0.001 mmHg at 25°C). Lower molecular weight hydrocarbons will volatilize quickly from the soil surface to the atmosphere. However, if used mineral-based crankcase oil is spilled on soil, volatilization may be the major loss mechanism over long periods of time because the oil is resistant to leaching and degradation and characteristically remains on the soil surface (DOE 1989). Abiotic degradation was measured in a laboratory weathering experiment by placing a mixture of 80% used mineral-based crankcase oil and 20% No. 6 sludge (a mixture typically applied to roads) into a shallow pan. The mixture was subjected to simulated weathering stresses (wind and sunlight for 12 days); a 16-18% loss of weight was attributed to volatilization (Freestone 1979).

Hydrocarbons, such as highly branched alkanes and PAHs with three or more rings, are transported in soil runoff to surface water and settle out of the water column into the sediment where they may persist for many years (Brown et al. 1985; Wakeham and Carpenter 1976). Most hydrocarbons in used mineral-based crankcase oil have estimated water solubilities of less than 1 mg/L and soil partition coefficients of 10,000-1,000,000. These values indicate that used mineral-based crankcase oil will strongly adsorb to soils. Low molecular weight nitrogen- and sulfur-containing molecules, various additives, and solubilized metals in the mixture may be more mobile (DOE 1989; Vasquez-Duhalt and Greppin 1986).

When exposed to water, the various water-soluble fractions of used mineral-based crankcase oil will separate with their concentrations increasing with increasing agitation. Concentrations released from a 1:10 oil-to-water mixture have ranged from 54.4 $\mu\text{g/L}$ to 198 $\mu\text{g/L}$ for benzene, 516 $\mu\text{g/L}$ to 781 $\mu\text{g/L}$ for toluene, a nondetectable level to 0.17 $\mu\text{g/L}$ for ethylbenzene, and 172 $\mu\text{g/L}$ to 339 $\mu\text{g/L}$ for xylenes. The ranges were affected by the length of agitation with the lower concentration being measured after 0.5 hours and the higher concentration being measured after 24 hours of agitation. These ranges provide the upper ranges of concentrations that can be found in groundwater where the soil is contaminated with used motor oil. Other water soluble fractions of used motor oil include naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, acenaphthylene, phenanthrene, anthracene, fluoranthene, acenaphthene, pyrene, and chrysene. Additional compounds detected in the water soluble fractions include naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, phenanthrene, and acenaphthene. In the previous study, iron, copper, cadmium, lead, nickel, and zinc were also detected in the water soluble fractions (Chen et al. 1994).

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Studies have shown that used lubricating oil when applied to soil degrades without significant contamination of the surrounding soil and groundwater. This degradation is due to bacteria and fungi which can degrade the components of used lubricating oil (Neal et al. 1977; Rittmann and Johnson 1989). The degradation process is faster when the oil is applied to soil that has been previously exposed to oil due to the increased numbers of the degrading bacteria (Rittmann and Johnson 1989). To increase the degrading ability of the soil, oil-degrading bacteria that have been cultured in a lab can be applied to the soil. The speed of the degradation process decreases after a period of time due to the increase in concentrations of oil components that are harder to degrade (Rittmann and Johnson 1989). Another method of increasing the degradation of oil involves the addition of nitrogen and phosphorus to the soil (Neal et al. 1977; Rittmann and Johnson 1989). An oil decomposition rate of approximately 1 pound per cubic foot of soil per month was recorded in one study when commercial fertilisers were added to the soil (Neal et al. 1977). Additional increases in the rate of degradation can be obtained by tilling the soil to provide aeration (Elsavage and Sexstone 1989; Raymond et al. 1976; Rittmann and Johnson 1989). A study of soil degradation of waste oil emulsion used as a coolant showed a 96% decrease in the concentration of pristane and hexadecane. This decrease was not seen in sterilized soil. Soil with a higher rate of hexadecane biodegradation also showed a corresponding higher rate of respiration. The fatty acids contained in the waste emulsion were broken down within 28 days. Plants were observed to grow on the soil immediately after cessation of the oil application, although it must be noted that in this study the waste oil did not contain the metals found in waste crankcase oil. In soil cores, the majority of the applied compounds remained within the top 48 cm, and the components were not detected in significant concentrations in the groundwater below the site (Elsavage and Sexstone 1989).

Used mineral-based crankcase oil applied to rural roads for dust suppression can be transported to the air, water, and soil by several mechanisms: volatilization, runoff, capillary action, adhesion to dust particles, or adhesion to passing vehicles (Freestone 1972, 1979). Factors affecting the transport of used mineral-based crankcase oil include its viscosity, volatility, presence of surface-active agents, soil porosity, weather conditions, time to first rain after oil application, presence of oil-consuming microorganisms, and road conditions. Only 1% of the estimated amount of used mineral-based crankcase oil applied to two rural roads in New Jersey remained on the top 1 inch of the road surface material (Freestone 1979). This estimate was based on calculations using measurements of oil in the surface of the road, and assumptions that two applications were completed per year for 12-20 years at an application rate of 0.05 gallon/foot² for each application. The majority of oil transport occurred via

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runoff after the first few rainfalls following the oil application. During dry periods, the primary forms of transport were volatilization and dust transport. Dust particles may be carried by wind and contaminate crops located near the oiled roads. Samples were taken from oil on the banks of a stream near a road treated with used mineral-based crankcase oil and from the treated road. Fluorescent spectral analysis displayed similar hydrocarbon properties from each sample, indicating that the oil was reaching the stream and was deposited on the banks during a period of high stream flow (Freestone 1979).

Hydrocarbons from used mineral-based crankcase oil in stormwater were associated primarily with particulates (86.4%), indicating that adsorption to particles is an integral method of transport (Freestone 1979; Hunter et al. 1979). Once used mineral-based crankcase oil becomes adsorbed to particulate matter, diatomics are lost through natural weathering (MacKenzie and Hunter 1979). During a storm, the particulates are washed into the sewers and are eventually deposited in the sediments of the receiving water, especially if combined sewers are utilized and the treatment facility is bypassed (Freestone 1979; Hunter et al. 1979; MacKenzie and Hunter 1979). In one laboratory simulation of oil transport by runoff from oil-treated sand roads, the primary mechanism of transport was flotation of oil-wet sand particles. After two simulated monthly rainfalls, 20% of the oil-wet sand particles were transported by runoff from the road surface, and the applied used mineral-based crankcase oil had leached 1 mm into the clay surface of the road (Freestone 1979).

Used mineral-based crankcase oil can affect marine organisms in several different ways. These effects are categorized as lethal and sublethal toxicity by contact, physical coating by the oil, incorporation of the oil into tissues, and habitat alteration (Moore and Dwyer 1974). The effects of used mineral-based crankcase oil on marine organisms depends upon the nature of the oil to which the organism is exposed. The PAHs present in oil are known carcinogens and are found throughout the ocean in the residual fractions of crude oil and can concentrate in animal tissue (Hyland and Schneider 1976). Uptake of PAHs in marine fish and shellfish occurs via absorption of hydrocarbons on the skin, via dissolved hydrocarbons from the water diffusing through the skin, by transport across the gill membranes, and through ingestion of hydrocarbon-contaminated food (Connell and Miller 1981). This uptake is due primarily to the fact that aquatic organisms reach chemical homeostasis with the surrounding water (Moore and Dwyer 1974).

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In Williams et al., lobsters (*Homarus americanus*) were exposed to a surface slick of 25 mL diesel oil. PAH accumulations were observed in hepatopancreas tissue and tail muscle at days 3 and 4 of the experiment. The route of exposure for the lobsters was determined to be via absorption of dissolved hydrocarbons through the gills (Williams et al 1989b). Nine PAHs commonly detected in used mineral-based crankcase oil were found to bioconcentrate in bivalve mollusks (*Mercenaria mercenaria*) within 48 hours of initial exposure (*in vitro* exposure for 48 hours). Uptake of the PAHs was directly related to the weight of the mollusks. PAHs were maintained at detectable levels (the average total PAH concentration was 1522.55 ng/g wet tissue weight; the detection limit not reported) at the end of a 45-day depuration period, suggesting that mollusks may not be able to metabolize PAHs into water-soluble metabolites that are easily secreted (Tanacredi and Cardenas 1991). Laboratory studies on *Melitu nitidu* Smith, an estuarine amphipod, showed decreased survivability among the juveniles when exposed to 100 ppm waste oil in sediments. The females' ability to reproduce decreased as the sediment concentration of waste oil increased. This was due to morphological abnormalities in the reproductive structures (Borowsky et al. 1993).

Studies on exposure of fish to used mineral-based crankcase oil have shown that rainbow trout (*Oncorhynchus mykiss*) exposed to waste crankcase oil exhibited an increase in liver, kidney, and heart mixed-function oxidase (MFO) activity along with a corresponding increase in bile metabolites. Maximum levels were reached in days 1-4 and returned to basal levels by day 12. The threshold level for increased liver activity was 3 mg of PACs (polycyclic aromatic compounds) per kilogram of fish (Upshall et al. 1993). Carp (*Cyprinus carpio*) exposed to 50 ppb diesel 2 oil within 3 days exhibited an increase of bile fluorescence to a level 5.8-fold higher than unexposed carp. A saturation level representing a 12-fold increase in bile fluorescence was reached after 12 days of exposure (Britvic et al. 1992). Used mineral-based crankcase oil has also been shown to have negative effects on the growth of tadpoles (*Hyla cinerea*) as compared to the control groups (Mahaney 1994).

Earthworms found in the soil 10 meters from a roadway were soil-purged and found to accumulate up to 670 ppm cadmium and 331.4 ppm lead, attributed to used mineral-based crankcase oils deposited on road surfaces. These metal levels may be lethal to earthworm predators (such as amphibians, reptiles, birds, and mammals) and may have a detrimental effect on the food chain (Gish and Christensen 1973). Metals can also accumulate in roadside plants through foliar absorption or root uptake (Falahi-Ardakani 1984).

5.3.2 Transformation and Degradation

5.3.2.1 Air

The major removal processes of particles in the air, including aerosols of used mineral-based crankcase oil, are coagulation, which leads to larger particle sizes that sediment out of the atmosphere and scavenging by precipitation. Hydrocarbons are removed from the air by chemical and photochemical reactions. Many of these reactions lead to the formation of free radicals. When photosensitized, metal oxides may promote the oxidation of hydrocarbons (Manahan 1979). Photochemical transformation has been considered to be the most important method of atmospheric decomposition of PAH in both the gas phase and as particulates (Baek et al. 1991).

When used mineral-based crankcase oil is burned, metals, organics, sulfur dioxide, nitrogen dioxide, acid halides, and particulates are released into the atmosphere. Metals such as lead and zinc, in particular, are emitted in substantial quantities. The majority of organic compounds in used mineral-based crankcase oil are destroyed during combustion. When used mineral-based crankcase oil is applied to roads as a dust suppressant, volatilization can occur which results in its components being released into the atmosphere (Canadian Environmental Protection Act 1994). Moderately volatile metals such as arsenic, cadmium, lead, zinc, and nickel compounds will nucleate to form particles in the submicron size range. Metals of low volatility such as barium, chromium, nickel, and tin will either vaporize incompletely and nucleate onto solids emitted during combustion or form large-sized particles (Entropy 1994).

5.3.2.2 Water

When automotive lubricating oil comes into contact with water, a partitioning of various volatile organic compounds, polynuclear aromatic hydrocarbons, and metals takes place. The hydrocarbons found in motor oil consist mainly of naphthenes and aromatic compounds with smaller amounts of paraffins. The ratio of these constituents determines the physical properties of the oil such as viscosity and viscosity-temperature-pressure characteristics. In a study by Chen et al. (1994), the partition coefficients of aromatic compounds from motor oil to water were estimated using Raoult's law to determine equilibrium conditions for the water-to-oil positioning. Compounds detected in the water-soluble fractions of used motor oil include naphthalene, 1-methylnaphthalene, 2-methylnaphthalene,

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acenaphthalene, phenanthrene, anthracene, fluoranthene, acenaphthene, pyrene, and chrysene. No phenols were detected in the water-soluble fractions. The metals detected in the water-soluble fractions were iron, copper, lead, nickel, and zinc. The concentrations of the solutes introduced into the water increased with increasing agitation of the oil-water mixture (Chen et al. 1994).

The various constituents of used mineral-based crankcase oil undergo several weathering processes following a spill. These include volatilization, sinking, emulsification, agglomeration, photodegradation, and biodegradation, depending on the chemical and physical nature of the compounds (Canadian Environmental Protection Act 1994).

Metals found in used mineral-based crankcase oil did not inhibit the growth of *Pseudomonas fluorescent* bacteria, possibly because the metals were not in a form that the bacteria could assimilate. However, when the metabolic rate exceeded the growth rate during bacterial biodegradation, metals were transferred from the oil phase to the aqueous phase. A fraction of the metals in the aqueous phase was immobilized by adsorption, precipitation, or assimilation during bacterial growth. The amount of metals solubilized was dependent on the equilibrium between growth and metabolism. The transfer from the oil phase to the aqueous phase involved an increase in metal persistence, mobility, and toxicity (Vasquez-Duhalt and Greppin 1986).

5.3.2.3 Sediment and Soil

Used mineral-based crankcase oil released to the soil surface is subject to weathering stresses because the two primary loss mechanisms, volatilization and aerobic microbial degradation, are very slow. Microbial degradation of hydrocarbons is highly dependent on the chemical and physical properties of the hydrocarbon fractions present and on environmental conditions. When used mineral-based crankcase oil penetrates through the soil to the soil/groundwater interface, microbial degradation and hydrolysis processes, which are effective in degrading typical hydrocarbons, are not effective in degrading the less soluble aromatic and high molecular weight aliphatic constituents. Used mineral-based crankcase oil is also resistant to oxidation because anti-oxidants are added to crankcase oil when originally formulated (DOE 1989). Initial resistance to biodegradation may be attributed to the inability of the large hydrocarbon molecules to pass through the cell walls to be degraded within the bacteria. Consequently, the bacteria use extracellular enzymes, and therefore biodegradation is delayed during the adaptation period (DOE 1989). In soils that were previously exposed to oil, the rate of

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degradation increased because of the maintenance of a microbial population with the capacity to degrade hydrocarbons (Elsavage and Sexstone 1989; Neal et al. 1977).

Sediments in the Delaware River near the outfall of a sewage treatment plant were sampled, and the sulfur profile of the hydrocarbons was found to be analogous to the hydrocarbon profile of used mineral-based crankcase oil and stormwater runoff. The presence of high-boiling aromatic sulfur compounds and other hydrocarbons suggested that degradation did not occur in the sediments (MacKenzie and Hunter 1979).

A single application of 2.98 L/m² of used mineral-based crankcase oil from automobiles and trucks to field soil plots in Pennsylvania (silt loam), Oklahoma (sandy loam), and Texas (clay loam) was degraded by 55-82% (oil from automobiles) and 24-53% (oil from trucks) over 1 year (Raymond et al. 1976). Concentrations in fertilized fields of used mineral-based crankcase oil from automobiles and trucks decreased by 71-82% and 46-77%, respectively. The maximum rate of degradation was 0.60 L/m² each month. Cold ambient temperatures appeared to decrease the rate of degradation, and fertilizer application had little effect on the degradation until 50% of the oil was degraded. Following 50% degradation of the applied oil, the fertilizer-treated plots exhibited degradation rates 20% faster in Pennsylvania and 4% faster in Texas, compared to the unfertilized plots. The fertilizer-treated plots did not have significantly more used mineral-based crankcase oil degrading microorganisms compared to the unfertilized plots. Most of the degradation activity occurred in the top 10 cm of the soil, suggesting aerobic degradation. Most seeds germinated in treated and control plots; however, few plants survived and developed normally in both plots. Analyses suggested that an accumulation of lead affected the plants (Raymond et al. 1976).

Biodegradation of used mineral-based crankcase oil on road surfaces is minimal compared to losses from volatilization and runoff. Nevertheless, the degradation rate of used mineral-based crankcase oil on road surface material depends on the presence of hydrocarbon-consuming microorganisms, moisture content of soil, concentration of nitrogen and phosphorus, and ambient temperatures (Freestone 1979).

5.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

5.4.1 Air

Used mineral-based crankcase oil is not monitored in the air as a mixture but rather by its individual components, such as lead particulates and total hydrocarbons. The individual components may enter the atmosphere when used mineral-based crankcase oil is used as a fuel for boilers or waste disposal incinerators (API 1975; Cooper 1977; EPA 1974a; Mumford et al. 1986; NATO 1981), or it may be emitted directly with auto exhaust (Williams et al. 1989a). Models of emissions of a re-refinery in Buffalo, New York, produced estimates of hydrocarbons ranging from 4.87 to 10.56 $\mu\text{g}/\text{m}^3$ depending on atmospheric conditions at a distance of 150 meters from the source (Booth et al. 1983). The combustion of used mineral-based crankcase oil as 1-15% of the total fuel in power plants and other boilers resulted in measured ambient lead concentrations less than 5.0 $\mu\text{g}/\text{m}^3$ (0.005 mg/m^3) for 24-hour periods. The detection limit was not reported (Cooper 1977). Average concentrations were measured at 0.0001 $\mu\text{g}/\text{m}^3$ at a distance of 10,000 meters from the stack (API 1975).

Used mineral-based automotive crankcase oil was utilized as fuel in two waste oil heaters, an atomizing oil burner (AOB) and a vaporizing oil burner (VOB). The authors did not state if leaded or unleaded gasoline was used in the engines which produced the used mineral-based crankcase oil. In two separate test burns, the AOB emitted 20.9 and 224.45 mg/m^3 of particles $\leq 1 \mu\text{m}$ in diameter consisting primarily of antimony, chromium, copper, lead, magnesium, manganese, nickel, and zinc. The VOB emitted 0.22 and 18.2 mg/m^3 particles $\leq 3.0 \mu\text{m}$ in diameter primarily consisting of sulfur, zinc, aluminum, silicon, and lead (detection limits were not reported). Lead was present at concentrations up to 7.5% in the AOB emission particulates. The concentration of lead in the used mineral-based crankcase oil prior to combustion was 1,075 $\mu\text{g}/\text{g}$. An electrostatic precipitator was used for the two tests which emitted 20.9 and 0.22 $\mu\text{g}/\text{m}^3$ particulates. Combustion of used mineral-based automotive crankcase oil emitted greater levels of inorganic compounds compared to used mineral-based truck crankcase oil. Cadmium, cobalt, copper, iron, lead, phosphorus, and zinc exceeded the threshold limit values (time-weighted averages) in both of the waste oil heaters (Hall et al. 1983b; Mumford et al. 1986). In a separate study of emissions from a commercial boiler, a vaporizing pot burner, and an AOB, zinc concentrations in the stack were 34.8 mg/m^3 , 0.04 mg/m^3 , and 55.7 mg/m^3 , respectively. Emissions of other metals were reported to follow trends similar to those seen in the zinc concentrations (Canadian Environmental Protection Act 1994).

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A study comparing emissions of used crankcase oil with those of No. 2 fuel oil in air atomizing burners showed significantly higher emissions of hydrochloric acid, particulates, and lead from the used crankcase oil. Lead emissions from the used oil were 74 times higher than lead emission levels from the burning of No. 2 fuel oil. Results are from an average of tests from five different air atomizing burners with used oil from gasoline engines sampled in four of the tests and used oil from diesel engines sampled in the remaining test. The average concentrations were 346.25 mg/minute of HCl, 466.0 mg/minute of particulates, 1.6455 mg/minute of chromium, 20.8314 mg/minute of lead, and nondetectable levels of <0.2679 and <0.7428 mg/minute for arsenic and cadmium, respectively. Used crankcase oil emissions were still below applicable ambient standards (Vermont Agency of Natural Resources 1994).

The contribution of crankcase oil to exhaust particulate matter during a simulated urban drive cycle was analyzed by using ^{13}C -labelled lubricating oil. A C_{19} alkane was synthesized with a ^{13}C -labelled tracer and used in two vehicles initially registered in 1978 and 1981. Sampling was executed over a transient urban drive cycle with speeds ranging from 0 to 91 km/hour, with a mean value of 31.7 km/hour. The ^{13}C -labelled tracer demonstrated that 15% weight/weight of particulate matter emissions were attributable to crankcase oil. The percentage of particles $\leq 1 \mu\text{m}$ in diameter ranged from 70% to 90%, with a mean value of 85% (Williams et al. 1989a).

5.4.2 Water

The mean background concentration for total hydrocarbons is 2 $\mu\text{g/L}$ for ocean water (Tanacredi 1977). Ultraviolet-fluorescence and gas chromatography were used to determine the relationship between waste-water effluents in Jamaica Bay, New York, and used mineral-based crankcase oil. Although specific sources for waste petroleum products were not established, samples taken from Jamaica Bay displayed chromatographs and ultraviolet-fluorescence responses similar to those of used mineral-based crankcase oil (Tanacredi 1977).

Waste water from a waste oil refinery that was released into the Buffalo Sewer Authority System contained 44.8 and 78.0 mg/L of what was categorically referred to as "Hydrocarbon Oil & Grease" (Booth et al. 1983). Surface water samples from on-site ponds at an NPL site, the Double Eagle Refinery, an inactive waste-oil re-refining facility in Oklahoma City, Oklahoma, were analyzed for chromium, lead, toluene, xylene, and unspecified hydrocarbons. Only chromium, lead, and xylene

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levels were precisely measured and found to be 10, 118, and 14 µg/L, respectively (ATSDR 1990a). Another waste oil refinery was tested for inorganic and organic concentrations found in the waste water effluent. Inorganic concentrations measured were 0.34 mg/L for cadmium, 271 mg/L for lead, 3.4 mg/L for arsenic, 10 mg/L for chromium, 80 mg/L for barium, and 250 mg/L for zinc. Organic concentrations measured were 1,306 mg/L for toluene, 283 mg/L for naphthalene, 364 mg/L for benzene, and 309-666 mg/L for several unnamed chlorinated solvents. Benzo(a)anthracene and benzo(a)pyrene concentrations were below detectable limits (0.02mg/L) (Canadian Environmental Protection Act 1994).

Total extractable hydrocarbon levels from Jamaica Bay surface water ranged from 0.5 to 3.1 mg/L in 1973 and from 0.88 to 5.1 mg/L in 1974. Gas chromatographic sulfur fingerprints of the aromatic fraction of stormwater runoff in Delaware indicated that used mineral-based crankcase oil was the likely source of hydrocarbons. Concentrations of particles containing aromatics in the stormwater ranged from 0.99 to 1.65 mg/L (990-1,650 µg/L), and soluble aromatics ranged from 0.04 to 0.07 mg/L (40-70 µg/L). Detection limits were not reported (MacKenzie and Hunter 1979).

An estimated 7 million gallons out of 340 million gallons of oil drained from automobiles per year are dumped into sewers (Suprenant et al. 1983). Hydrocarbon concentrations were $2,037 \pm 127$ µg/L (Brown et al. 1985) and 8 mg/L (8,000 µg/L) (Hunter et al. 1979) in stormwater at the beginning of a storm, indicating a flushing effect, since the total flow-weighted hydrocarbon concentrations over storms ranged from 618 µg/L (Brown et al. 1985) to 5.30 mg/L (5,300 µg/L) (Hunter et al. 1979).

The concentrations of aliphatic hydrocarbons in runoff from two bridges in Seattle ranged from 6,000 to 24,000 µg/L, with a mean of 12,000 µg/L (Wakeham 1977). Only 1% of the hydrocarbons (25-250 µg/L; mean 100 µg/L) were n-paraffins. Gas chromatography suggested that the source of the hydrocarbons was used mineral-based crankcase oil. Crankcase oils are dewaxed and generally have few paraffins. Urban stormwater runoff had lower concentrations of aliphatic hydrocarbons, (200-7,500 µg/L; mean 1,200 µg/L) and similar to the bridge runoff, low levels of n-paraffins (4-350 µg/L; mean 13 µg/L). The chromatographic responses of used mineral-based crankcase oil and the hydrocarbons in the bridge runoff were very similar. The concentration of aliphatic hydrocarbons in the rivers and streams in the Seattle area varied with the season. During the rainy season, the hydrocarbon level was slightly higher; however, the paraffin concentrations remained low, ranging

from 0.1 to 1 $\mu\text{g/L}$, indicating the presence of hydrocarbons from used mineral-based crankcase oil (Wakeham 1977).

Total flow-weighted hydrocarbon concentrations in particulates from urban runoff in Rhode Island ranged from 16,400 to 34,000 $\mu\text{g/g}$ (mean $24,800 \pm 6570$ $\mu\text{g/g}$) in commercial areas, from 61,900 to 507,000 $\mu\text{g/g}$ (mean $211,000 \pm 189,000$ $\mu\text{g/g}$) in industrial areas, from 8,750 to 51,800 $\mu\text{g/g}$ (mean $24,800 \pm 19,900$ $\mu\text{g/g}$) near interstate highways, and from 15,700 to 59,800 $\mu\text{g/g}$ (mean $42,000 \pm 23,200$) near residential areas. A PAH signature of the runoff analysis was performed to confirm that the hydrocarbons originated from used mineral-based crankcase oil (Latimer et al. 1990).

5.4.3 Sediment and Soil

Aliphatic hydrocarbon levels in deep sediments (40-42 cm) samples ($n=20$) from Lake Washington in Seattle, Washington, ranged from 10 to 160 $\mu\text{g/g}$ with an average of 32 $\mu\text{g/g}$ for the entire lake. Surface sediments samples ($n=20$) ranged from 280 to 1,700 $\mu\text{g/g}$, with a mean of 1,400 $\mu\text{g/g}$. Surface samples were collected from areas near suspected hydrocarbon sources. Gas chromatographic analyses of the surface sediments indicate that the hydrocarbons were primarily from lubricating oils and pyrolysis products from automobiles that were transported by stormwater. Samples collected from two cores 94 cm deep showed an increase in hydrocarbon concentrations after 1880, which correlated with the industrial development of the area near the lake (Wakeham and Carpenter 1976). An analysis of sediment hydrocarbons from the Hillsborough Reservoir in Tampa, Florida, indicated that runoff from stormwater contaminated by used mineral-based crankcase oil was the likely source of the hydrocarbons. Aliphatic hydrocarbon concentrations ranged from 62 to 396 $\mu\text{g/g}$ dry sediment, and aromatic hydrocarbon concentrations ranged from 15 to 89 $\mu\text{g/g}$ dry sediment (Brown et al. 1985). Used mineral-based crankcase oil, determined by a lead concentration of 640 ppm in sediment samples, was detected 100 feet from an NPL site that was formerly a waste oil recycling facility in Moira, New York.

Chromium, lead, and unspecified hydrocarbons were detected in the sediments of on-site ponds at an inactive waste oil re-refining facility, which is also an NPL site. Only chromium was accurately measured on-site (89,000 $\mu\text{g/kg}$). Waste solids were reported to have been dumped 850 feet south of the facility, and the maximum concentrations of chromium and lead in the contaminated soil were 220,000 and 4,810,000 $\mu\text{g/kg}$, respectively (ATSDR 1990a).

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Background concentrations of used mineral-based crankcase oil hydrocarbons in roadside soil were 856 µg/g in industrial areas, 265 µg/g near highways, 38.9 µg/g in residential areas, and 138 µg/g in commercial areas. Metals such as cadmium, copper, lead, manganese, and zinc were also measured in roadside source materials. Concentration ranges were 0.02-3.40 µg/g for cadmium, 10.4-228 µg/g for copper, 123-1,410 µg/g for lead, and 47.8-655 µg/g for zinc (Latimer et al. 1990). Soil samples taken 47.7 meters from an oil-treated road in Hunterdon County, New Jersey, contained an average lead concentration of 24 mg/kg. Two soil samples taken from a drainage culvert that carried runoff had lead concentrations of 78 and 96 mg/kg (Freestone 1979). Lead deposition from auto exhaust is typically limited to within 100 feet of a road (Motto 1970); therefore, the high lead concentrations in soil samples near the oil-treated road in Hunterdon County were most likely caused by the application of used mineral-based crankcase oil originating from engines burning leaded fuel. As leaded gasoline was a significant source of lead in soils, the use of unleaded gasoline should result in a reduction of lead in used mineral-based crank case oils, and a stabilization or reduction of lead in soil near roadsides.

5.4.4 Other Environmental Media

Background concentrations of lead on road surfaces averaged 39 mg/kg, while lead levels on dirt roads treated with used mineral-based crankcase oil averaged 209.25 mg/kg. Hydrocarbon concentrations at the surface of crankcase-oil-treated roads ranged from 5,880.24 to 13,441.25 mg/kg with a mean of 8,169.63 mg/kg. Hydrocarbon concentrations 6 inches below the road surface ranged from 7.65 to 67.63 mg/kg with a mean of 30.82 mg/kg (Freestone 1979).

Ambient hydrocarbon concentrations were measured in street dust and roadside vegetation in Rhode Island (Latimer et al. 1990). The PAH distribution in the hydrocarbons was similar to that in used mineral-based crankcase oil, suggesting that used mineral-based crankcase oil was the source of the hydrocarbons. Concentrations of hydrocarbons in street dust were 157 µg/g in commercial areas, 3,490 µg/g in industrial areas, 1,680 µg/g near highways, and 353 µg/g in residential areas. In roadside vegetation, the concentrations ranged from 40.6 to 46.1 µg/g in commercial, highway, and residential areas; however, in industrial areas the concentration was 290 µg/g. (Latimer et al. 1990).

Cadmium and lead at concentrations of 620 ppm and 331 ppm, respectively, associated with used mineral-based crankcase oil, were found in earthworms near a highway. The levels in the soil-purged

earthworms were positively associated with traffic volume and negatively associated with distance from the highway (Gish and Christensen 1973).

Plants sampled from a field 150 feet from a road where used oil had been applied for dust suppression contained an average lead concentration of 33.5 mg/kg. The lead concentration in the soil of the field was 24.0 mg/kg. A possible mechanism of transport to the field was dust containing lead or oil from the road. The average lead concentration in the oiled section of the road was 209.25 mg/kg as compared to a lead concentration of 39.0 mg/kg in the un-oiled section of the road. Aquatic organisms living in a stream running perpendicular to the road showed no real trend in their lead concentrations from areas upstream of the road and areas downstream of the road (Freestone 1972).

The fluorescence analyses of marine benthic organism (*Mya arenaria*) extracts from Jamaica Bay, New York, and used mineral-based crankcase oil were almost identical; however, no concentrations were reported (Tanacredi 1977).

5.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

The general population may be exposed to used mineral-based crankcase oil when checking the engine oil level of a motor vehicle; however, the extent of exposure to used mineral-based crankcase oil is minimal under these conditions (Kahsnitz et al. 1982). Exposure may also occur to the general population from the prevalent use of used mineral-based crankcase oil as a chain lubricant on household machinery such as chain saws, sewing machines, hedge trimmers, and lawn mowers (Brinkman et al. 1982). Several incidents of lead poisoning in cattle have been attributed to the ingestion of used mineral-based crankcase oil drained in pastures (Osweiler et al. 1973). Individuals who eat meat or dairy products from contaminated cattle may be exposed to excessive lead concentrations.

Occupational exposure to used mineral-based crankcase oil exists for engine mechanics who change crankcase oil or work with automobile parts contaminated with used mineral-based crankcase oil. However, exposure is likely to be low because most automobile repair shops have implemented procedures to reduce worker exposure (Kahsnitz et al. 1982).

Transport of used mineral-based crankcase oil through the soil from a contaminated site and into groundwater may result in human exposure via ingestion of contaminated drinking water, or dermal absorption if the water is used for recreational purposes (ATSDR 1988, 1990a; DOE 1989).

5.6 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Motorists who maintain and service their own automobiles may increase their likelihood of exposure if they spend long periods of time in contact with used mineral-based crankcase oil contaminated auto parts or do not practice good personal hygiene (DOE 1989; Kahsnitz et al. 1982).

Workers involved in the remediation of environmental contamination from used oil re-refining or recycling facilities may inhale contaminated particulates or volatiles, or be dermally exposed to contaminated soil, sludge, sediment, or sorbent pads (ATSDR 1988, 1990a). Workers involved in collecting used mineral-based crankcase oil for recycling or re-refining may also be dermally exposed.

Individuals who work or live in buildings that burn used mineral-based crankcase oil for heating fuel may be exposed to high levels of metal particulates in the respirable range (Cooper 1977; Hall et al. 1983b; Mumford et al. 1986).

Individuals who live near roads that have been treated with used mineral-based crankcase oil as a dust suppressant may be exposed to dust particles which are contaminated with used oil.

5.7 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, as amended, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of used mineral-based crankcase oil is available. Where adequate information is not available, ATSDR, in conjunction with the NTP, is required to assure the initiation of a program of research designed to determine the health effects (and techniques for developing methods to determine such health effects) of used mineral-based crankcase oil.

The following categories of possible data needs have been identified by a joint team of scientists from ATSDR, NTP, and EPA. They are defined as substance-specific informational needs that if met would

reduce the uncertainties of human health assessment. This definition should not be interpreted to mean that all data needs discussed in this section must be filled. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda will be proposed.

5.7.1 Identification of Data Needs

Physical and Chemical Properties. The physical and chemical properties of used mineral-based crankcase oil as a mixture are not well defined, and data should be gathered in order to estimate the fate of this oil and its components in the environment. Data needs associated with some specific compounds that are components of used mineral-based crankcase oil (e.g., PAHs, lead, cadmium, and zinc) are presented in the ATSDR profiles for these chemicals (ATSDR 1990c, 1993b, 1992d, 1989b, respectively).

Production, Import/Export, Use, Release, and Disposal. In 1972, 500 million gallons of used mineral-based crankcase oil were produced in the United States, and in 1982, production increased to 1,350 million gallons (API 1974; Brinkman et al. 1982; Maugh 1976; Vasquez-Duhalt 1989; Weinstein 1974). More recent data on the production of used mineral-based crankcase oil are needed. Used mineral-based crankcase oil has been used as a supplemental fuel for boilers, waste disposal incinerators, and cement kilns (API 1975; Cooper 1977; EPA 1974a; Hall et al. 1983a; Mumford et al. 1986; NATO 1981). Most releases of used mineral-based crankcase oil are the result of illegal disposal and runoff from highways and rural roads. The environmental media most likely to be contaminated by used mineral-based crankcase oil are water, soil, and sediment. Current disposal methods are not satisfactory, since a national survey of disposal methods indicated that 40% of used mineral-based crankcase oil is poured onto the ground, 21% is placed in the trash to be collected, 14% is recycled, and 25% is used for other purposes (Brinkman et al. 1982). Used mineral-based crankcase oil is regulated by EPA and by the individual states. All states except West Virginia recognize road oiling for dust suppression as an important route of exposure and regulate for this release. Further regulations for used mineral-based crankcase oil are expected in the future.

According to the Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. Section 11023, industries are required to submit substance release and off-site transfer information to the EPA. The Toxics Release Inventory (TRI), which contains this information for 1993, became available in

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May of 1995. This database will be updated yearly and should provide a list of industrial production facilities and emissions. However, no data for used mineral-based crankcase oil are included in TRI.

Environmental Fate. Used mineral-based crankcase oil partitions to various environmental media depending on the physical and chemical properties of its individual components. Major fate processes include slow volatilization of lower weight aliphatic and aromatic hydrocarbons, and sorption of higher molecular weight hydrocarbons to soil (DOE 1989). Slow microbial degradation is the primary loss mechanism for hydrocarbon fractions not lost through volatilization (DOE 1989; Raymond et al. 1976). Metals may be solubilized during microbial degradation, consequently increasing their mobility and toxicity (Vasquez-Duhalt and Greppin 1986). Used mineral-based crankcase oil is usually transported to surface water by stormwater runoff. Hydrocarbons that settle out of the water column into the sediment are persistent (Brown et al. 1985; Wakeham and Carpenter 1976). The half-life of used mineral-based crankcase oil in soil and water has not been established; therefore, further studies are required. The environmental fate of some of the individual components has been studied (see ATSDR profiles for PAHs, cadmium, lead, and zinc [ATSDR 1990c, 1992d, 1993b, 1989b]). The environmental fate and behavior of used mineral-based crankcase oil have not been well characterized. Consequently, further data is needed on movement and persistence of the components of used mineral-based crankcase oil in all environmental media.

Bioavailability from Environmental Media. There are limited animal data on the absorption of used mineral-based crankcase oil by the inhalation, oral, or dermal routes. However, several of the components of used mineral-based crankcase oil are known to be absorbed. For more information on absorption of the individual components (e.g., lead, cadmium) see the ATSDR toxicological profiles on these compounds (ATSDR 1993b, 1992d). Limited animal data regarding lead poisoning related to the ingestion of used mineral-based crankcase oil indicate that lead from this source is distributed to various tissues (Osweiler et al. 1973). Limited data exist on absorption of lead in plants grown in contaminated soil (Raymond et al. 1976) and absorption of PAHs by marine organisms in contaminated water (Tanacredi 1977; Tanacredi and Cardenas 1991); however, more data are needed to determine whether the components of used mineral-based crankcase oil are likely to enter the food chain. Additional data on rates and extent of absorption through inhalation, oral, and dermal routes may be helpful in determining bioavailability from environmental media.

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Food Chain Bioaccumulation. Used mineral-based crankcase oil, as a mixture, does not bioconcentrate in the food chain. However, the individual components may bioconcentrate depending on their physical and chemical properties. Metals, especially lead, have been found to bioconcentrate in crops and cause abnormal growth (Falahi-Ardakani 1984; Raymond et al. 1976). Limited information was also located on the bioconcentration of used mineral-based crankcase oil components in terrestrial animals and aquatic organisms (Osweiler et al. 1973; Tanacredi 1977; Tanacredi and Cardenas 1991). Research on the biomagnification of used mineral-based crankcase oil would not be useful because the oil is not available to the food chain as a mixture. However, further research on the biomagnification potential of the individual components of used mineral-based crankcase oil may be helpful in assessing the risk associated with eating foods grown in contaminated soil.

Exposure Levels in Environmental Media. Most monitoring studies assessed the concentration of used mineral-based crankcase oil in stormwater runoff and sediments, although limited data exist on hydrocarbon and metal concentrations in surface water, air, marine benthic organisms, roadside plants, and cattle (Brown et al. 1985; Falahi-Ardakani 1984; Freestone 1979; Gish and Christensen 1973; Hunter et al. 1979; Latimer et al. 1990; MacKenzie and Hunter 1979; Osweiler et al. 1973; Tanacredi 1977; Van Donkelaar 1990; Wakeham 1977). Limited data are available from monitoring studies near hazardous waste sites. Lead was detected in sediments and groundwater near a hazardous waste site (ATSDR 1988), and chromium and lead were detected in soil near another hazardous waste site (ATSDR 1990a). However, the sampling at each site was not comprehensive, and the validity of the results could not be verified. Estimates should also be developed for human intake of used mineral-based crankcase oil from environmental media. Recent data on levels of used mineral-based crankcase oil and its components in environmental media, especially groundwater, are needed to further assess potential risk from likely sources of exposure. There are no known populations with extraordinarily high exposure to used mineral-based crankcase oil.

Reliable monitoring data for the levels of used mineral-based crankcase oil in contaminated media at hazardous waste-sites are needed so that the information obtained on levels of used mineral-based crankcase oil in the environment can be used in combination with the known body burden of used mineral-based crankcase oil to assess the potential risk of adverse health effects in populations living in the vicinity of hazardous waste sites.

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Exposure Levels in Humans. This information is necessary for assessing the need to conduct health studies on these populations. There is no specific biomarker of exposure to used mineral-based crankcase oil in humans; therefore, biological monitoring studies are not recommended. See other ATSDR profiles (PAHs, lead, zinc, and cadmium) for levels of used mineral-based crankcase oil components detected in human tissue (ATSDR 1990c, 1992d, 1993b, 1989b, respectively).

Exposure Registries. No exposure registries for used mineral-based crankcase oil were located. This substance is not currently one of the compounds for which a subregistry has been established in the National Exposure Registry. The substance will be considered in the future when chemical selection is made for subregistries to be established. The information that is amassed in the National Exposure Registry facilitates the epidemiological research needed to assess adverse health outcomes that may be related to exposure to this substance.

5.7.2 On-going Studies

No on-going studies on the exposure or environmental fate of used mineral-based crankcase oil were located.