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5.1   OVERVIEW

JP-5 and JP-8 are complex mixtures of aromatic and aliphatic hydrocarbons whose exposure potentials are based on the mixtures themselves and on the individual components of the mixtures (primarily n-alkanes, branched alkanes, benzene and alkylbenzenes, naphthalenes, and PAHs, particularly in the case of environmental exposures once degradation begins). There are few methods for analyzing the environmental fate of jet fuels *per se*; instead, methods are used to analyze the proportions of the component hydrocarbons of jet fuels.

Jet fuel may be released to the environment by in-flight jettisoning of fuel and from spills or leaks to soil or water during use, storage, or transportation. Jet fuel jettisoned from planes can be transported via airborne dispersion, and some of it can be transformed photochemically to ozone and other components of smog. Jet fuel may form aerosols as a result of reactions with atmospheric chemicals, but the specific composition of the particulate material is not known. Most of the jet fuel released to water evaporates into the air. The more volatile components of jet fuels (low molecular weight alkanes) evaporate from soil and water and enter the atmosphere where they are degraded. Components with higher boiling points persist longer in soil and water. Some components of JP-5 and JP-8 are soluble in water (e.g., the aromatics–benzene, toluene, and xylene). Under turbulent water conditions, the more soluble hydrocarbons remain dissolved longer and may partition to soils and sediments and be biodegraded. The rate and extent of biodegradation are dependent on the ambient temperature, the presence of a sufficient number of microorganisms capable of metabolizing the component hydrocarbons, the amount of aromatic species in the jet fuel, and the concentration of jet fuel. Some components also volatilize or migrate through the soil to groundwater.

The National Occupational Exposure Survey conducted by NIOSH between 1980 and 1983 estimated that 1,076,5 18 employees (including 96,255 females) were exposed to kerosene, a primary component of JP-5 and JP-8, in the workplace. Worker exposure was most likely in industries associated with machinery and special trade contractors. Populations most likely to be exposed to JP-5 and JP-8 include those involved in jet fuel manufacturing or refueling operations, populations near an area where JP-5 or JP-8 have been dumped, and populations working or living on military bases where the fuels are used or stored (and where leaks and spills are likely to occur).

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JP-5 and JP-8 have been found in at least 22 of the 1,445 current or former EPA National Priorities List (NPL) sites (HazDat 1997). However, the number of sites evaluated for JP-5 and JP-8 is not known. The frequency of these sites can be seen in Figure 5-1. Of these sites, all are located in the United States.

5.2   RELEASES TO THE ENVIRONMENT

JP-5 and JP-8 are fuel mixtures used by the U.S. military and NATO as aviation fuels. As a result of normal aircraft operations and fuel storage, JP-5 and JP-8 can be released into the environment. Under some conditions, it is common practice for aircraft to jettison excess fuel into the air, releasing it into the environment (IARC 1989).

Releases of JP-5 and JP-8 are not required to be reported under SARA Section 313; consequently, there are no data for these compounds in the 1992 TRI (TR192 1994).

5.2.1   Air

JP-5 and JP-8 may be released into the air as vapors during aircraft loading and unloading operations or as a result of their normal use as a jet fuel for military aircraft (Air Force 1981a; NIOSH 1989). Releases into the air may also occur as a result of volatilization of JP-5 or JP-8 from contaminated soils or spill sites (Air Force 1989b). Atmospheric emissions of jet fuels may be determined primarily by detection of their volatile hydrocarbon components.

5.2.2   Water

Jet fuels may be released into surface water or groundwater as a result of leaking storage tanks and pipelines, surface runoff of unburned fuel residue, airborne jettisoning of fuels, and spills during dispensing operations and aircraft maintenance (Guiney et al. 1987a; Klein and Jenkins 1983). Leakage of jet fuels including JP-5 from storage tanks at the Patuxent Naval Air Test Center (NATC), Patuxent River, Maryland, has resulted in "severe environmental insult" to a Navy fuel farm and adjacent areas (Navy 1988). During the winter of 1976-l 977 a pipeline connecting underground storage tanks ruptured, releasing an undetermined amount of JP-5 and other jet fuels into the subsurface system. The existence and possible extent of groundwater contamination are unknown; however, surface waters near the site are known to be contaminated with jet

Figure 5-1. Frequency of NPL Sites with JP-5 and JP-8 Contamination*
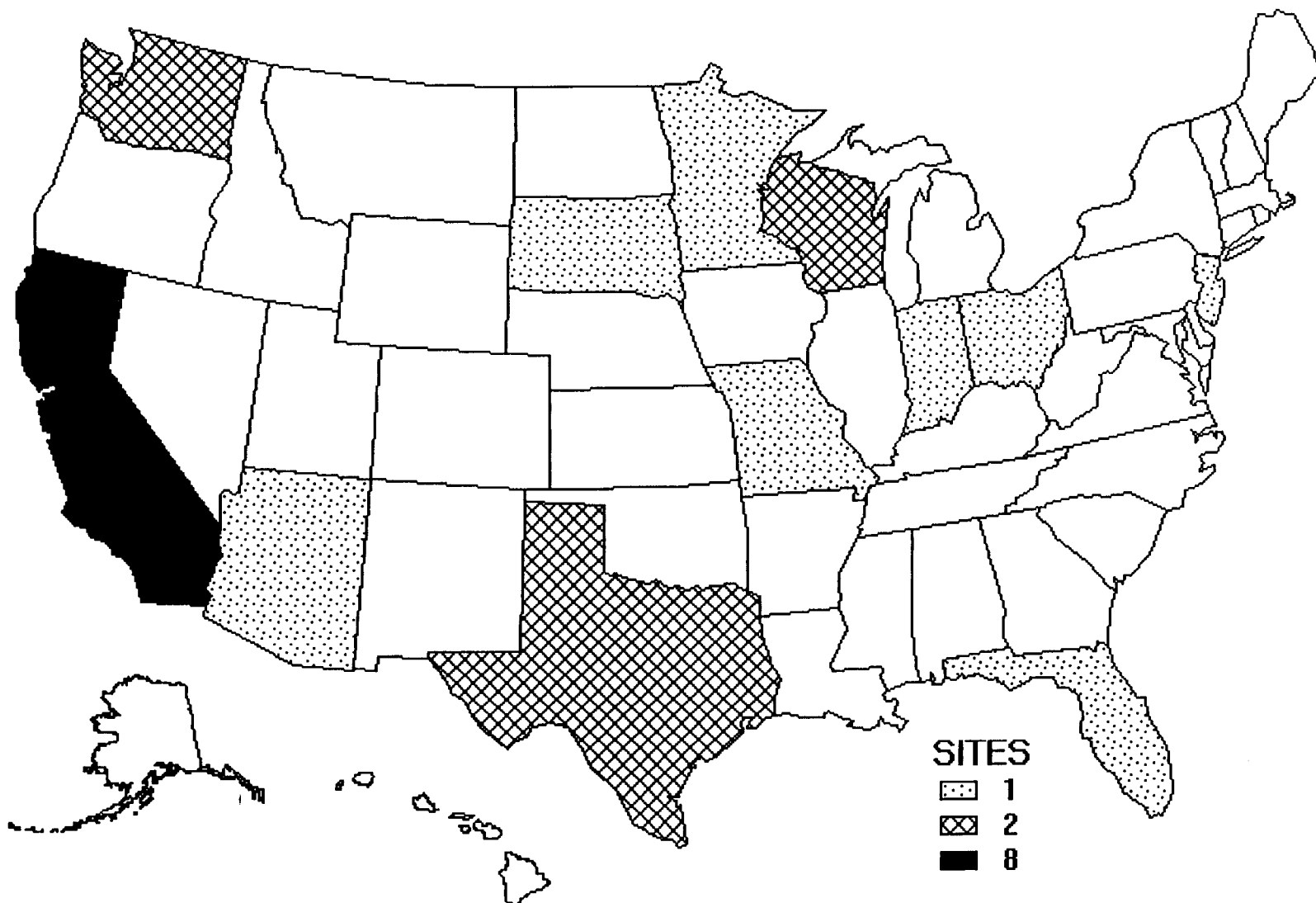
SITES
- ⬚ 1
- ⬚ 2
- ⬛ 8

*Derived from HazDat 1997

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fuels including JP-5 (Arthur et al. 1992). On October 16, 1982, a crack in a petroleum pipeline near
Ebensburg, Pennsylvania, released an estimated 1,3 10 barrels of "aviation kerosene" into a stream (Guiney et
al. 1987a).

5.2.3   Soil

JP-5 and JP-8 may be released into soil as a result of accidental spills and leaks in underground or
aboveground storage tank systems. From March to June 1971, an accidental spill released more than 14 tons of
JP-5 jet fuel mixed with jet fuel no. 2 at a storage facility in Searsport, Maine (Dow et al. 1975). During the
winter of 1976-1977, soils at a fuel farm at Patuxent NATC, Patuxent River, Maryland, were
contaminated with an unknown quantity of JP-5 when a pipeline connecting underground storage tanks
ruptured (Arthur et al. 1992). Since that time, site investigations have revealed that the fuel has moved
through several acres of sandy soil to a depth of 20-30 feet (Arthur et al. 1992).

5.3   ENVIRONMENTAL FATE

5.3.1   Transport and Partitioning

The transport and dispersion of JP-5 and JP-8 are dependent on the water solubility and volatility of the
component hydrocarbon fractions. Lower molecular weight hydrocarbons such as n-alkanes may volatilize
relatively quickly from both water and soil, while larger aliphatics (greater than C_9 chain length) may be
sorbed to organic particles in water or soil. Aromatic hydrocarbons will be dissolved in the aqueous phase in
both soil and water and may undergo some volatilization. Information on the specific physical and chemical
properties of several of the component hydrocarbons (e.g., benzene, toluene, xylene, and naphthalene) can be
found in the ATSDR toxicological profiles for these chemicals. The many hydrocarbons that compose JP-5
and JP-8 can be divided into a few groups of hydrocarbon classes with similar properties (Air Force 1989b).
These include paraffins (also called alkanes, which are saturated straight-chain hydrocarbons), cycloparaffrns
(saturated cyclic hydrocarbons), aromatics (fully unsaturated cyclic compounds), and olefins (also called
alkenes, which are unsaturated straight-chain and cyclic hydrocarbons). Paraffins and cycloparaffins (alkanes
and cycloalkanes) are the major hydrocarbon components of JP-5 and JP-8 and together constitute
approximately 80-90% by volume of the fuels (IARC 1989). Aromatics constitute approximately 17% of JP-8
and 18% of JP-5 (Army 1988). It is important to point out that the specific composition of jet fuels varies
among manufacturers and probably among batches (Air Force 1989a; DOD 1992). JP-5 and JP-8 may

also contain low levels of nonhydrocarbon contaminants and additives including sulfur compounds, gums, naphthenic acids, antioxidants, static inhibitors, icing inhibitors, and corrosion inhibitors (DOD 1992; IARC 1989).

Transport processes have been shown to be more significant than transformation processes in determining the initial fate of lower molecular weight petroleum hydrocarbons released to soil and groundwater systems (Air Force 1989b). Evaporation from water is the major removal process for low molecular weight, volatile hydrocarbons, such as those found in JP-5 and JP-8 (EPA 1983). Loss of JP-8 from water was determined to be primarily due to evaporation in a quiescent flask test system study (Dean-Ross et al. 1992). Loss of individual hydrocarbon components of JP-8 was related to molecular weight and vapor pressure, with low molecular weight components (toluene and n-octane) being removed within 10 days, and high molecular weight components (1-methylnaphthalene and n-dodecane) persisting (Dean-Ross et al. 1992). Laboratory experiments have shown that the evaporation rate of jet fuel and its components increases with wind velocity and, to a lesser extent, with temperature and fuel-layer thickness (Air Force 1988). Comparisons of dissolution and evaporation rates under several wind-speed and mixing conditions showed that evaporation was the dominant fate process for jet fuel components in water.

In a study by Coleman et al. (1984), the partitioning of kerosene (the primary constituent of JP-5 and JP-8) into drinking water after 17 hours of incubation resulted in only 0.7% of the kerosene being dissolved in the water. Further analysis of the kerosene indicated that although kerosene contains approximately 50% aliphatic hydrocarbons (by weight percent), the water-soluble fractions (WSFs) contained primarily aromatic constituents (>93%) including benzenes and naphthalenes as shown below (Coleman et al. 1984).

		Water-soluble fraction	
	Whole product*	1/2 hour	17 hours
Kerosene			
Alkanes + cycloalkanes	68.6	4.5	0.5
Benzene + substituted benzenes	13.7	63.5	53.2
Naphthalene + substituted naphthalenes	5.7	29.6	44.8

*Estimated weight percent

JP-8 also evaporates from soil, although evaporation in not as important a fate process in soil as it is in water. When water/sediment slurries were treated with JP-8, rates of removal were much slower than from water

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alone. The addition of sediments to water inhibited the evaporative removal of JP-8, apparently by adsorbing the components of JP-8 and thus rendering them unavailable for evaporation (Dean-Ross et al. 1992).

Horizontal and vertical migration of JP-5 has been demonstrated by field observations and laboratory experiments. Model soil core terrestrial ecosystems and outdoor soil cores were treated with JP-5 to mimic a spill and watered to simulate rainfall (Air Force 1982a). The individual hydrocarbon components of JP-5 were found to vertically migrate to varying depths in quantities independent of one another, apparently independent of aqueous leachate movement. Movement of JP-5 in the laboratory occurred to a depth of 50 cm with the majority of hydrocarbons being transported in the first 10 cm. Of the 14 hydrocarbons present, only one component, 1,3,5-trimethylbenzene, was detected below 20 cm. Hydrocarbon components did not persist past the 131st day of the experiment. The outdoor soil core showed movement of JP-5 to a 30-cm depth. The majority of hydrocarbons were seen at 10,20, and 30 cm. Hydrocarbon components were detectable in the core until the 173rd day of the experiment (Air Force 1982a). Horizontal and vertical migration of jet fuels has also been confirmed by detection of JP-5 hydrocarbons in soil several meters from the spill site (Arthur et al. 1992).

The movement of a synthetic kerosene through soil was found to be dependent on the moisture content of the soil. The greater the moisture content (e.g., 4% compared with 0.8%) of the soil, the less the adsorption of the more volatile components of the kerosene and the greater and more rapid the penetration of the liquid component through the soil. Conversely, the upward mobility of both the liquid and vapor phases of kerosene through soil decreased with increased moisture content, and at field capacity, the upward capillary movement of the kerosene was completely inhibited (Acher et al. 1989). Desorption of a simulated kerosene applied to three types of soil, each with a moisture content at 70% of field capacity, was found to be complete after 30 days of exposure to the atmosphere with the slowest desorption from the soil having the greatest organic content (Yaron et al. 1989). Kerosene loss from a dune sand, a loamy sand, and a silty loam soil after 50 days showed that volatilization of all kerosene components was greatest from the dune sand and loamy sand soils. The larger pore size of these types of soil compared with the silty loam soil was thought to be the reason for the increased volatilization (Galin et al. 1990a). Movement of kerosene through three grades of sand was affected mainly by volatilization of the C_9–C_{13} components with a subsequent increase in the viscosity of the remaining kerosene residue and a decrease in the infiltration rate through the inert porous media (Galin et al. 1990b).

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The movement of kerosene through various types of soil over a 12-hour period was studied. Upward, downward, and lateral movement was greatest in soil of the mica/kaolinite type (11% clay content)–40, 102, and 45 cm, respectively. Movement through soils that were primarily kaolinite (clay content of 26-52%), regardless of the direction, ranged between 20 and 33 cm (EPA 1986). Application of herbicides such as S-ethyl dibutylthiocarbamate to a field using kerosene as a solvent (up to a volume of 40 gallons per acre) increased the inactivation of the herbicide on soil, whereas acetone, benzene, and xylene did not. The accelerated inactivation possibly resulted from a change in surface tension that facilitated the volatilization of the herbicide from the soil (Danielson and Gentner 1970).

Studies on the permeability of compacted micaceous soil used as a potential liner for landfills found that the permeability of the soil to kerosene varied from three to four orders of magnitude greater compared with water (EPA 1984).

Aquatic organisms are known to bioconcentrate hydrocarbons. Flagfish exposed to concentrations of 1.0-6.8 mg/L JP-8 in surrounding water (from the egg stage to posthatching) have been found to accumulate JP-8 (Klein and Jenkins 1983). The mean concentration of JP-8 in whole-body tissue samples increased with increasing concentration of the WSF of the fuel. The bioconcentration factor (BCF), expressed as the ratio of the concentration in tissue to the concentration of the WSF of JP-8 in the aqueous environment, was found to be 159 (log value = 2.2). Adult flagfish exposed to 2.54 mg/L, for 14 days yielded a BCF of 130 (log value =2.1). Adult flagfish that were placed in uncontaminated water exhibited a depuration rate similar to the accumulation rate. Similar experiments with rainbow trout showed no relationship between JP-8 concentrations in surrounding water and whole-body concentrations in the fish. The relatively low BCF of 63-l 12 (log value = 1.8-2.1) calculated for rainbow trout indicates that the WSF of JP-8 does not concentrate as readily in this species.

5.3.2   Transformation and Degradation

5.3.2.1   Air

No studies on the transformation or degradation of JP-5 or JP-8 in the atmosphere were located. However, volatile components of jet fuels such as benzene, toluene, xylenes, and PAHs may be expected to enter the atmosphere where they are subjected to degradation processes. Further information on the atmospheric degradation of selected volatile hydrocarbons is presented in the ATSDR toxicological profiles for these

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chemicals (ATSDR 1989, 1990, 1995a, 1995b). Studies on JP-4, a jet fuel mixture of gasoline and kerosene, indicate that jet fuels react photochemically in air in the presence of nitrogen oxide compounds to form ozone, but the effect of temperature on the nitrous oxide oxidation rate is uncertain (Air Force 1981 b, 1982b). Reactions of JP-4 produce large amounts of aerosol material (Air Force 1981b), and it should be noted that JP-4 has a considerable gasoline component compared to straight kerosene.

5.3.2.2   Water

Biodegradation of jet fuels is dependent on the degradation of the various hydrocarbon fractions present in the oils. The relative order for biodegradation of the hydrocarbon fractions from the most readily degraded to the least is as follows: *n*-alkanes, iso-alkanes, olefins, low molecular weight aromatics (at low, nontoxic concentrations), PAHs, and cycloalkanes (Bartha and Atlas 1977; Edgerton et al. 1987).

Conflicting data exist on the biodegradation of jet fuels and kerosene. Biodegradation of JP-8 in water was studied using quiescent flask test systems (Dean-Ross et al. 1992). Microbial activity in flasks of water incubated at 30°C on a shaker at 200 revolutions per minute for 4 days was inhibited by all concentrations of JP-8 tested (0.0l%, 0.l%, 1%), as indicated by a depression of glucose mineralization in comparison to a control. The study authors suggested that one possible explanation for the lack of biodegradation in water samples is the toxicity of JP-8 to microorganisms, which may severely inhibit microbial activity (Dean-Ross et al. 1992).

Microorganisms readily able to degrade hydrocarbons were found in the Neuse River estuary in North Carolina. Although the estuary was relatively free of hydrocarbon contamination, 63% of the bacteria and 71% of the fungi isolated from surface water samples were able to utilize kerosene as the sole carbon source (Buckley et al. 1976). Weathered kerosene (volatile components were allowed to escape prior to testing) was spiked with four hydrocarbon markers, and the degradation of the markers was monitored. All four markers were degraded by a water-sediment mixture from an "oiled arm" of an Ohio lake; more rapid-degradation was associated with mixtures taken from relatively polluted areas of the lake (Cooney et al. 1985), suggesting that biodegradation is enhanced by the presence of acclimated microorganisms. Marine bacteria capable of using jet fuel no. 1 were isolated from Narragansett Bay, Rhode Island. Most of the bacteria were found to utilize the aliphatic components of the jet fuel, primarily hexadecane, while only a few of the bacteria were able to degrade the aromatic components. The bacteria were able to degrade the hexadecane at 0 °C, but degradation was significantly improved when the incubation temperature was increased to 8 °C and 16 °C; similar but not

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such dramatic effects were seen in the degradation of naphthalene with increased temperature (Cundell and Traxler 1976).

Petroleum residues were measured in the northern Arabian Sea to assess the contamination following the oil spills resulting from the Gulf War in 1991. Little change in variables related to oil pollution took place in any compartment of the marine environment-water, plankton, fish, or sediments (Sengupta et al. 1993).

5.3.2.3   Sediment and Soil

Ample evidence exists to indicate that kerosene, JP-5, and JP-8 are biodegraded in soil. Microbial degradation in soils is greatest for the aromatic fractions of jet fuels, while the biodegradation of the aliphatic hydrocarbons decreases with increasing carbon chain length. Evaporation is the primary fate process for these aliphatics (Air Force 1989b).

Application of JP-5 to terrestrial soil core ecosystems and outdoor soil cores resulted in a stressed condition as indicated by an increased rate of carbon dioxide (CO_2) production within 1 day of application (Air Force 1982a). The carbon dioxide production of the cores returned to a rate almost comparable to that of the controls following the increase. A possible reason for this increase was increased activity of microorganisms that utilize the component hydrocarbons of JP-5. The study authors concluded that soil microbes are able to degrade JP-5 in cultures inoculated with soil organisms (Air Force 1989a). In a quiescent flask study, JP-8 was found to be nontoxic to sediment microorganisms (Dean-Ross et al 1992). The study authors found that removal of some components of JP-8 from active soil (soil containing microorganisms) was significantly faster than removal in sterilized soil. Subsurface microorganisms present at a fuel spill at Patuxent NATC were able to utilize JP-5 as their sole carbon source (Navy 1988). The study author concluded that potential exists for promoting *in situ* biodegradation of some of the hydrocarbon components by stimulating the growth of indigenous microflora. Although most soils contain microorganisms capable of degrading hydrocarbons *in situ,* the factors that limit the bioremediation process (e.g., restricted bioavailability of the contaminant, nutrient limitations, potential toxicity of fuel hydrocarbons and associated contaminants, inadequate reduction/oxidation [redox] potential, inadequate or excessive moisture, acidic or basic conditions, and oxygen deficiency) need to be overcome in order to stimulate the degradation of jet fuels in soil and groundwater (Arthur et al. 1992).

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The degradation of kerosene in soil was studied when a pipeline ruptured and showered a wheat field with kerosene. After 6 months, the kerosene concentration began to decrease in the upper 30 cm of soil (with C_{13}-C_{17} n-alkanes disappearing more rapidly compared with C_{10}-C_{12} *n*-alkanes) and at 21 months was reduced to trace amounts; however, kerosene was still detected at soil depths of 30-45 +cm. The study authors interpreted this as indicating reduced aerobic biodegradation at this depth, especially since the compounds disappeared in the order of their preferential microbial utilization. Seed germination studies using the contaminated soil 1 year after the spill (0.34% kerosene concentrations) showed that kerosene delayed seed germination but that the percent germination was unaffected (Dibble and Bartha 1979). Landfarming techniques (tillage of soil using agricultural implements) developed in The Netherlands to enhance biodegradation of contaminants demonstrated that after one growing season, kerosene (initial concentration of 1,000-10,000 mg/kg dry matter) was significantly degraded (final concentration of 500 mg/kg dry matter) in 40 cm of soil (Soczo and Staps 1988).

The addition of nitrogen (as urea) to soil increases the biodegradation potential of kerosene; however, kerosene was found to inhibit the urease activity of soil microbes by up to 35%, suggesting that sources of nitrogen other than urea should be used (Frankenberger 1988). The bacterial species in the genera *Achromobacter,* Pseudomonas, and *Alcaligenes,* isolated from the soil of an active oil field in Louisiana, were able to aerobically degrade kerosene as determined by oxygen uptake (Cooper and Hedrick 1976). Soil *Pseudomonas* were able to degrade kerosene to a greater extent than were *Enterobucter* with stationary phases occurring after 10 days and 8 days, respectively (Butt et al. 1988). Seven years after the dumping of sludge containing kerosene at two sites, vegetation at each site showed little recovery. Although the bacterial biomass had declined at both sites, microbial activity, as determined by carbon dioxide evolution, was greater at the site that had received more precipitation and had the more aerated soil (Jones 1977).
Oxidation of kerosene by soil microbes, as determined by dehydrogenase activity, increased with increasing loading rates (up to 60% w/w oil/dry soil) for up to seven days of incubation but decreased thereafter. Dehydrogenase activity in soil treated with kerosene was 32 μg formazan/g soil/24 hours (Frankenberger and Johanson 1982).

5.4   LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to JP-5 and JP-8 depends in part on the reliability of supporting analytical data from environmental samples and biological specimens. In reviewing data on JP-5

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and JP-8 levels monitored or estimated in the environment, it should also be noted that the amount of chemical identified analytically is not necessarily equivalent to the amount that is bioavailable. The analytical methods available for monitoring JP-5 and JP-8 in various environmental media are detailed in chapter 6.

5.4.1   Air

JP-5 and JP-8 can enter the atmosphere through evaporation from spills and leaks, vaporization during fueling operations, and burning in engines. In a "third generation closed aircraft shelter," which has approximately three times the interior volume of a "first generation closed aircraft shelter," the concentration of JP-8 in the air was measured as 12 mg/m^3 during refueling operations. In the immediate vicinity of the refueler technician, JP-8 concentrations were determined to be below 22 mg/m^3 (Air Force 198la). In contrast, concentrations of JP-4 (a more volatile jet fuel than either JP-5 or JP-8) ranged from 75 to 267 mg/m^3 in a similar structure during fueling operations. Concentrations of JP-4 in a first-generation shelter ranged from 533 to 1,160 mg/m^3 (Air Force 1981a).

A study by Puhala et al. (1997) examined jet fuel vapor exposures at three U.S. Air Force bases in the United States. At the time of sampling, JP-8 was only used at one base, JP-5 and JP-8 at another, and a third used only JP-4. Breathing zone samples were collected for workers in aircraft maintenance, fuel handling, and flight-line positions.

Mean exposure concentrations for all samples collected were 0.01 ppm benzene (SD=0.0l) and 1.33 ppm naphthas (SD=l.95) for aircraft maintenance positions; 0.01 ppm benzene (SD=0.0l) and 0.61 ppm naphthas (SD=0.90) for fuel handling positions, and 0.004 ppm benzene (SD=0.005) and 0.33 ppm naphthas (SD=0.40) for flight-line positions.

5.4.2   Water

No data were located that discussed specific levels of JP-5 or JP-8 in water. During October of 1983, a leaking pipeline south of Ebensburg, Pennsylvania, released approximately 1,310 barrels of "aviation kerosene" into a trout stream (Guiney et al. 1987a, 1987b). Total organic carbon (TOC) content in the stream water was approximately 30-60 ppm during the initial few months following the spill, which is approximately 1.5-2 times greater than background (Guiney et al. 1987b). During the winter of 1976-1977,

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a leak of unknown quantity in a pipeline at Patuxent NATC in Maryland resulted in surface water
contamination and possible groundwater contamination by JP-5 (Arthur et al. 1992).

5.4.3   Sediment and Soil

No data were located that discussed specific levels of JP-5 or JP-8 in sediments and soil. An unknown
quantity of JP-5 leaked from a pipeline during the winter of 1976-1977 at Patuxent NATC in Maryland,
resulting in several acres of soil contamination to a depth of 20-30 feet (Arthur et al. 1992).

5.4.4   Other Environmental Media

No data were located that discussed specific levels of JP-5 or JP-8 in other environmental media such as
foodor terrestrial or aquatic plants and animals. Concentrations of kerosene-range hydrocarbons in fish
collected during the year following an "aviation kerosene" leak into a trout stream ranged from 2.60 to 14.37
ppm by weight (Guiney et al. 1987b). Shellfish taken from unpolluted waters have been found to contain
between 1 and 12 μg/g wet weight of total hydrocarbons, while fish have been found to contain between 4 and
14 μg/g total hydrocarbons (steam distillable) (Connell and Miller 1980).

5.5   GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

The National Occupational Exposure Survey, conducted by NIOSH between 1980 and 1983, estimated that
1,076,518 employees were exposed to kerosene in the workplace (NOES 1992).

Exposure of the general population to JP-5 and JP-8 is most likely to be limited to populations living on or
near a military installation where JP-5 or JP-8 are utilized. Unintentional exposure to JP-5 and JP-8 may
occur as a result of groundwater contamination from spilled jet fuels or contact with soils that have been
contaminated with jet fuels. Occupational exposure will occur in individuals involved in the production of
kerosene and JP-5 and JP-8, fueling and defueling aircraft, and cleaning up spills and leaks of jet fuel.

5.6   POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Military workers involved in fueling and defueling operations may be exposed to higher levels of JP-5 and
JP-8 than members of the general population (Air Force 1981a). Maintenance workers who monitor jet fuel

storage tanks may be exposed to JP-5 and JP-8 via inhalation of jet fuel vapors. Maintenance workers may

also be dermally exposed to jet fuels while sampling, gauging, and draining water (condensation) from fuel

storage tanks (NIOSH 1989). Workers in the petroleum industry may receive intermittent inhalation, oral,

and dermal exposure to kerosene and jet fuels during the refining process. Exposure is most likely to occur

during the distillation of crude oil, when monitoring and servicing of equipment are carried out, or when

sampling must be done (Runion 1988). Use of a respirator, protective clothing, and increased ventilation can

all reduce worker exposure to jet fuel vapor. The use of JP-8 rather than JP-4 reduces occupational exposure to

jet fuel vapors for maintenance workers and pilots because the vapor pressure of JP-8 is an order of magnitude

less than JP-4 at 38°C. This results in less vapor being vented from JP-8-fueled aircraft than JP-4-fueled

aircraft (Air Force 1981a). The similarly low volatility of JP-5 suggests that reduced exposure to JP-5 vapors

will also occur in aircraft fueled with JP-5.

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 JP-5 and JP-8 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

JP-5 and JP-8.

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 JP-5 and JP-8 (kerosene)
and their primary component chemicals are well defined and can be used to estimate the fate of these jet fuels
following release to the environment (Air Force 1989b; IARC 1989). However, because jet fuels are
complex mixtures of hydrocarbons, their environmental fate is determined by both the characteristics of the

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mixture and the individual components, making modeling based on physical and chemical properties difficult. Data needs associated with specific compounds that are components of JP-5 and JP-8 (e.g., benzene, toluene, xylene, and PAHs) are presented in the ATSDR toxicological profiles for these chemicals (ATSDR 1989, 1990,1995a, 1995b).

Production, Import/Export, Use, Release, and Disposal. According to the Emergency Planning and Community Right-to-Know Act of 1986,42 U.S.C. Section 11023, industries are required to submit chemical release and off-site transfer information to the EPA. The Toxics Release Inventory (TRI), which contains this information for 1994, became available in May of 1996. This database will be updated yearly and should provide a list of industrial production facilities and emissions.

JP-5 and JP-8 are used primarily as military aviation fuels (Air Force 1989b; IARC 1989). Most releases of jet fuels are the result of in-flight jettisoning of fuel and spills either on land or water (Arthur et al. 1992; IARC 1989). Few data are available on current production and import/export volumes for JP-5 and JP-8. Further information on the production volumes for each jet fuel, environmental releases, and disposal of jet fuels would aid in assessing the potential for human exposure as a result of accidental or intentional release.

Environmental Fate. The environmental fate of JP-5 and JP-8 is based on the environmental partitioning of the major hydrocarbon fractions. For aliphatic hydrocarbons, volatilization of lower molecular weight alkanes and sorption to organic matter for larger aliphatics, followed by biodegradation, are the primary degradation processes (Air Force 1982a; Cooney et al. 1985; Dean-Ross et al. 1992). Aromatic components are most susceptible to biodegradation in warm water or soil, although some volatilization may occur in colder waters (Walker et al. 1976). Jet fuel contaminants that migrate through soil may contaminate groundwater. The deposition of aliphatics from the water column may persist for over a year (Oviatt et al. 1982). Jet fuel that spills or leaks into soil can migrate both vertically and horizontally (Air Force 1982a). JP-5 and JP-8 jettisoned into the atmosphere probably contribute photochemically to the formation of ozone and particulates (Air Force 1981b, 1982b), and some of the fuel components and reactant products are probably transported via wind dispersion. Environmental fate data needs associated with specific compounds that are components of JP-5 and JP-8 (e.g., benzene, toluene, xylene, and PAHs) are presented in the ATSDR toxicological profiles for these chemicals (ATSDR 1989, 1990, 1995a, 1995b). Information on light- and chemical-mediated reactions of jet fuel components would aid in determining the fate of JP-5 and JP-8 in soil and water. More information on the fate of individual components of JP-5 and JP-8 under varying environmental conditions, including the interaction of JP-5 and JP-8 with different soil types, would be

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helpful in determining any horizontal and vertical migration patterns of jet fuels in contaminated groundwater systems.

Bioavailability from Environmental Media. The extent of absorption of JP-5 and JP-8 by inhalation, oral, and/or dermal routes is unknown. However, toxicity data are available for humans exposed to jet fuels and kerosene by each of these routes (Porter 1990; Subcommittee on Accidental Poisoning 1962). These data indicate that absorption does occur. The extent of absorption by these routes depends on the volatility, solubility, lipophilicity, and other properties of the specific jet fuel components. Several of these component compounds have been discussed in their individual ATSDR toxicological profiles (e.g., benzene, toluene, xylene, and PAHs), which should be consulted for further information (ATSDR 1989, 1990,1995a, 1995b). More data linking exposure levels of jet fuels with biological levels of component chemicals would be useful in determining which chemicals in the mixture are most likely to be absorbed and by which routes. This information would aid in determining daily human exposure levels and more accurately assessing the risks associated with exposure to jet fuels.

Food Chain Bioaccumulation. Data on the bioaccumulation of JP-8 in flagfish, rainbow trout, and golden shiners suggest that bioaccumulation and biomagnification are low (Klein and Jenkins 1983). Aquatic organisms are able to bioaccumulate some hydrocarbon fractions; however, depuration occurs if the source of the contamination is removed (Klein and Jenkins 1983). JP-5 and JP-8 are expected to separate into their individual hydrocarbon components in the environment, and the bioaccumulation potentials of these components are believed to be independent of each other. Further studies are needed to determine the biomagnification potentials of these components up the food chain within aquatic and terrestrial ecosystems. Specific research needs are presented in the individual ATSDR toxicological profiles on specific hydrocarbon components such as benzene, toluene, xylenes, and PAHs (ATSDR 1989,1990a, 1995a, 1995b). Research on the biomagnification of jet fuels as actual mixtures would not be useful because they are not available to the food chain as mixtures.

Exposure Levels in Environmental Media. Reliable monitoring data for the levels of JP-5 and JP-8 in contaminated media at hazardous waste sites are needed so that the information obtained on levels of JP-5 and JP-8 in the environment can be used in combination with the known body burden of JP-5 and JP-8 to assess the potential risk of adverse health effects in populations living in the vicinity of hazardous waste sites. There is limited information available on the levels of jet fuels found in air, soil, or water where jet fuels are used or stored. Some information exists on the levels of JP-8 in the air in closed buildings during refueling

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operations (Air Force 198 1 a). Very little information is available for JP-5 or JP-8 concentrations in soil, water, and other environmental media (Arthur et al. 1992; Guiney et al. 1987a, 1987b; Navy 1988). More data on levels of jet fuels or their components in the environmental media around facilities where jet fuels are produced, stored, and used would be useful to assess the potential risk from these likely sources of exposure.

Reliable monitoring data for the levels of JP-5 and JP-8 in contaminated media at hazardous waste sites are needed so that the information obtained on levels of JP-5 and JP-8 in the environment can be used in combination with the known body burdens of JP-5 and JP-8 to assess the potential risk of adverse health effects in populations living in the vicinity of hazardous waste sites.

Exposure Levels in Humans. Populations known to have an increased risk of exposure to JP-5 and JP-8 and their component hydrocarbons include: workers who manufacture or use the fuels; workers involved with monitoring and servicing jet fuel storage tanks; people living or working on military installations where jet fuels are used or stored; and populations living or working near a spill, leak, or dump site (Air Force 1981a; NIOSH 1989; Runion 1988). Further information is needed to assess the approximate levels of exposure for these populations. This information is necessary for assessing the need to conduct health studies on these populations.

Exposure Registries. No exposure registries for JP-5 and JP-8 were located. These substances are 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   Ongoing Studies

An investigation into the development of JP-8 with improved thermal oxidative stability isbeing conducted by the U.S. Air Force (FEDRIP 1994). The U.S. Navy is conducting an investigation into developing a membrane extraction process for shipboard recovery of the JP-5 icing inhibitor additive from water separated from JP-5 aviation turbine fuel. This technology will enable reblending of the additive (FEDRIP 1994).

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As part of the Third National Health and Nutrition Evaluation Survey (NHANES III), the Environmental Health Laboratory Sciences Division of the National Center for Environmental Health, Centers for Disease Control and Prevention, will be analyzing human blood samples for JP-5 and JP-8 and other volatile organic compounds. These data will give an indication of the frequency of occurrence and background levels of these compounds in the general population.