ATSDR

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Case Studies in Environmental Medicine

32

Jet Fuel Toxicity

Environmental ALERT . . .

- ***Jet fuels (JP-4 and JP-7) are complex mixtures of hydrocarbons with small amounts of additives. JP-4 is a general purpose fuel used widely throughout the U.S. military; JP-7 is used in specialized supersonic aircraft.***
- ***Environmental levels of jet fuels may be high near refueling operations, in enclosed aircraft shelters, and inside the cockpits of certain jet aircraft.***
- ***Spilled jet fuels evaporate rapidly from surface water but can contaminate groundwater and soil for years.***

This monograph is one in a series of self-instructional publications designed to increase the primary care provider's knowledge of hazardous substances in the environment and to aid in the evaluation of potentially exposed patients. See page 19 for more information about continuing medical education credits and continuing education units.

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U.S. DEPARTMENT OF HEALTH & HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

ATSDR

How to use this issue...

This issue begins with a composite case study that describes a realistic encounter with a patient. This description is followed by a pretest. The case study is further developed through Challenge questions at the end of each section. To fully benefit from this monograph, readers are urged to answer each question when it is presented. (Answers to the Pretest and Challenge questions are found on pages 17-18.) The monograph ends with a posttest, which can be submitted to the Agency for Toxic Substances and Disease Registry (ATSDR) for continuing medical education (CME) credit or continuing education units (CEU). See page 19 for further instructions on how to receive these credits.

The objectives of this monograph on jet fuels are to help you

- ❑ **Explain why JP-4 and JP-7 may be acute and chronic health hazards**
- ❑ **Describe the factors that may contribute to poisoning by JP-4 and JP-7**
- ❑ **Identify potential environmental and occupational sources of exposure to JP-4 and JP-7**
- ❑ **Identify evaluation and treatment protocols for persons exposed to JP-4 and JP-7**
- ❑ **List sources of information on JP-4 and JP-7**

Contents

This issue is prepared with the assistance of those who share a common concern for physician education, public health, and the environment, including the following organizations: Aerospace Medical Association, American Academy of Clinical Toxicology, American Academy of Family Physicians, American Academy of Pediatrics, American College of Emergency Physicians, American College of Occupational and Environmental Medicine, American Medical Association, Association of State and Territorial Health Officials, and the Society of Teachers of Family Medicine. This issue was created at the request of the U.S. Air Force through interagency funding. Final responsibility for the contents and views expressed in this monograph resides with ATSDR.

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Case Study

A 35-year-old woman with acute delirium, memory deficits, and fatigue

A 35-year-old woman is brought to your office by her husband, who found her in an agitated state when he arrived home from his job as an aircraft mechanic at a nearby Air Force base. Although the patient is not completely coherent, she attempts to describe an incident that occurred earlier in the day.

While standing in her backyard, she saw a jet pass overhead at a very low altitude. The plane appeared to be in trouble and shortly after it passed by, drops of liquid rained down. She felt a burning sensation on her skin, so she immediately took a shower. While in the shower, she noticed a strong odor and began to feel "drunk." She had smelled a similar kerosene-like odor on several occasions while bathing and using hot water for other purposes, but today it was particularly strong.

On further questioning, the patient mentions that she has been experiencing atypical mood changes over the past few months and has had trouble remembering things. She cites the example of going to the supermarket and not remembering what she intended to buy. She also states that she has headaches and is frequently fatigued. She has no history of psychiatric problems and denies alcohol or drug use.

On physical examination, you find an anxious woman 5'4" tall and weighing 156 pounds. Her blood pressure is 140/90 mm Hg. Pulse is 80/minute and regular. She is afebrile. The skin on her arms and face shows signs of redness with some dry scaling. The skin is well hydrated with normal turgor. There are no stigmata of liver disease. The thyroid is not enlarged, and no cervical lymphadenopathy is present. There are no murmurs, pulse deficits, or aberrations in heart sounds; cardiac rhythm is normal. Examination of the abdomen is unremarkable but is hindered because of body fat. Normal bowel sounds are present. Neurologic examination reveals 1^+ deep tendon reflexes, normal motor findings, and mild ataxia. Sensory examination indicates mildly diminished pinprick sensation in the extremities. Memory tests are not performed at this time because of the patient's continued state of apparent anxiety.

Results of routine laboratory tests are within normal limits for CBC, urinalysis, and the following blood chemistries: glucose, electrolytes, BUN, and creatinine.

(a) What should be included in the patient's problem list?

(b) What are some disease states that could explain this patient's problems?

(c) What additional laboratory tests would you order for this patient?

(d) How will you treat this patient?

Answers to the Pretest questions are on page 17.

Exposure Pathways

- **JP-4 is a general purpose aviation turbine fuel and constitutes 85% of the aviation fuel used by the military.**

JP-4 and JP-7 are grades of jet propulsion (JP) fuel developed by the U.S. Air Force for use in aviation turbine engines. JP-4 is a fuel for general-purpose jet aircraft and constitutes about 85% of the aviation fuel used by the military. JP-7 is similar to JP-4 but has greater thermal stability and a higher flash point. JP-7 is used in specialized supersonic aircraft.

Aviation fuels for turbine engines differ slightly from Avgas (aviation gasoline), the fuel used in reciprocating engines. Avgas is similar to automotive gasoline in that the same blending stocks (i.e., C_4-C_{12} hydrocarbons) are used in preparing both. (See *Case Studies in Environmental Medicine: Gasoline Toxicity.*) To meet the special requirements of aviation fuels (i.e., high octane, high energy, and freezing-point below –36°F [–58°C]), greater percentages of some blending stocks and more tetraethyl lead are required.

- **JP-7 is a blended kerosene that is used in advanced supersonic aircraft.**

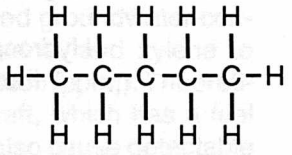
All aviation fuels consist primarily of hydrocarbon compounds; namely, straight-chain and branched-chain alkanes (paraffins), cyclic alkanes (naphthenes), alkenes (olefins), and aromatic hydrocarbons (Figure 1), with additives that are determined by the specific uses of the fuel. The major components of fuels used in fixed-wing aircraft are paraffins and cycloparaffins, which have a higher hydrogen-to-carbon ratio (i.e., greater energy content) and burn cleaner than do aromatic hydrocarbons. Additives include metal deactivators, antioxidants, static dissipators, octane boosters, and corrosion and ice inhibitors.

The composition of jet fuels can be very complex (Table 1). JP-4 is considered a wide-cut, naphtha-type fuel composed mainly of alkanes in the C_4 to C_{16} range. JP-7 is produced by blending kerosenes; detailed information on the composition of JP-7 is not generally available. The actual chemical composition of these jet fuels varies somewhat and is determined by required performance. In addition to the hydrocarbon base formulation, both fuels contain additives. JP-4 is a colorless to light-brown, flammable liquid with an odor similar to motor oil. Its odor can be detected at about 1 part per million (ppm) in air. Other names for JP-4 are MIL-T-5624-L-Amd.1 wide cut, and JP-4 military (gasoline-type). Information on the appearance, odor threshold, and physical properties of JP-7 are not available in the general literature. JP-7 is also known as MIL-T-38219A-Amd.2, and kerosene, low volatility. Aviation fuels, like automotive gasoline, have a specific gravity of 0.6 to 0.7; hence, they float on water.

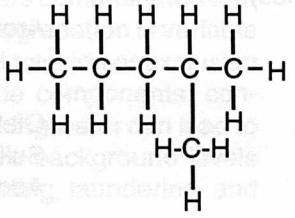
Figure 1. Structures of the hydrocarbon components of aviation fuels

Alkanes (Paraffins)

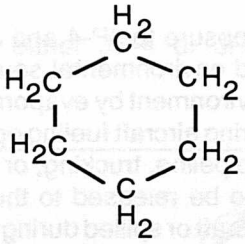
(a) Straight Chain



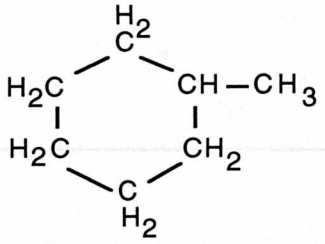
(b) Branched Chain



(c) Naphthenes

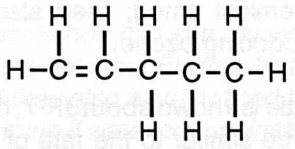


Cyclic

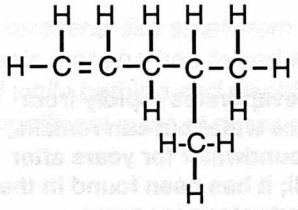


Branched Cyclic

Alkenes (Olefins)

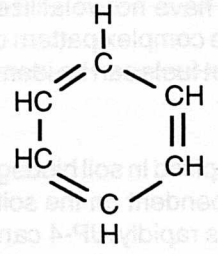


(a) Straight Chain

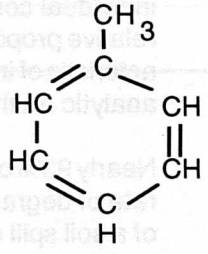


(b) Branched Chain

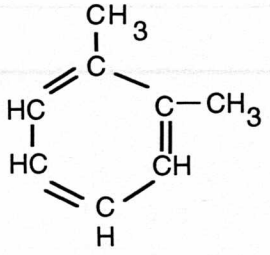
Aromatics



Benzene



Toluene



ortho-Xylene

Table 1. Chemical composition of JP-4 and JP-7 by volume

JP-4	JP-7
Hydrocarbons (C_4–C_{16})	Hydrocarbons
Paraffins (75%-90%)	Paraffins (major)
n-alkanes (including ~22% n-hexane)	
branched alkanes	
cycloparaffins (naphthenes)	cycloparaffins (major)
Aromatics (10%-25%)	Aromatics (maximum ~5%)
benzene (<0.5%)	
Naphthenes (~3%)	
Olefins (~5%)	Olefins
Sulfur, sulfur compounds	Sulfur, sulfur compounds (~0.1%)
Additives	Additives

Exposure to JP-4 and JP-7 can occur from both occupational and environmental sources. The fuels can be released to the environment by evaporation or leakage from fuel storage tanks; during aircraft fueling operations; in industrial waste streams; or in pipeline, trucking, or railroad leaks and accidents. They can also be released to the air and ground when jettisoned from aircraft or spilled during aircraft crashes. Vapors of JP-4 and JP-7 have been found inside hangars where aircraft operations are carried out. As with other fossil fuels, the combustion products of JP-4 and JP-7 may participate in the formation of photochemical smog; they also may react with nitrogen oxides, producing ozone.

- **JP-4 evaporates rapidly from surface water but can remain in groundwater for years after a spill; it has been found in the groundwater near some military bases.**

Little is known about JP-7, but its environmental fate is assumed to be similar to the fate of JP-4. The components of these jet fuels (primarily hydrocarbons that may vary in amount depending on the formulation) are expected to behave relatively independently in the environment. Because the components of jet fuels occur in many other petroleum products, determining whether an individual component is from jet fuel contamination can be difficult. However, if the contamination is recent and the individual components have not volatilized or changed in their relative proportions, the complex pattern of hydrocarbons characteristic of individual jet fuels can be identified by sophisticated analytic methods.

Nearly 93% of all JP-4 spilled in soil biodegrades slowly, with the rate of degradation dependent on the soil type. The remainder of a soil spill evaporates rapidly. JP-4 can remain in some soils for 20 years or more. It has been found at depths of 14 feet from spills from above- and below-ground storage tanks and supply pipes.

JP-4 evaporates rapidly when spilled in surface water. It may reach groundwater sources as a result of seepage from contaminated soils during storage, aircraft maintenance, and fuel storage and dispensing operations. JP-4 has been detected in groundwater near many U.S. military installations. An 83,000-gallon leak from a JP-4 storage tank at one military base caused groundwater concentrations of benzene, ethylbenzene, toluene, and xylene to reach 3 milligrams/liter (mg/L) (3 parts per million [ppm]). Theoretically, an incident involving a single jet aircraft, which has a fuel capacity of several thousand gallons, could also cause detectable contamination of a water supply. Selective aerobic biodegradation of component hydrocarbons in shallow aquifers contaminated with JP-4 has been documented, but the rate of degradation is variable depending on water source, conditions, and inclusion or exclusion of sediment. Because JP-4 contains volatile components, contamination of groundwater that supplies drinking water can lead to household ambient air concentrations above background levels during activities that use hot water (e.g., bathing, laundering, and cooking).

Current data provide no evidence that either JP-4 or JP-7 bioconcentrates in the food chain.

Challenge

(1) The patient in the case study mentioned that she has noticed a kerosene-like smell from the water but says the water does not taste unusual. Further history reveals that she has talked with some neighbors about the water, and they also have noticed the smell while bathing and washing dishes or clothes. How could you determine if water contamination is a significant route of exposure for this patient?

Who's at Risk

The National Institute for Occupational Safety and Health (NIOSH) has estimated that approximately 10,000 employees were occupationally exposed to JP-4 between 1980 and 1983. Persons most likely to be exposed to jet fuel(s) are those involved in jet-fuel refining, blending, formulation, transfer, and transport. Pilots, military flight-support personnel, and personnel employed in the manufacture and testing of jet-aircraft engines may also be exposed. Other frequent occupational exposures are associated with filling, draining, and maintaining fuel tanks; maintaining distribution tanks, pipelines, and engines; and performing laboratory sampling and analysis.

- **Persons at greatest risk for exposure to JP-4 or JP-7 are those involved in the manufacture, operation, and testing of jet engines; those involved in cleaning and maintaining fuel cells; and jet pilots.**

In one study, JP-4 was measured in the air of enclosed aircraft shelters at levels ranging from 533 milligrams/cubic meter (mg/m^3) to 1160 mg/m^3 (approximately 130 ppm to 282 ppm*), with the higher levels near refueling operations. The concentration of jet fuel in the breathing zone of aircraft fueling personnel was as high as 1020 mg/m^3. In the same study, a concentration of 1110 mg/m^3 was measured inside the cockpit of a U.S. F-4 fighter. Eight-hour, time-weighted-average (TWA) exposures in Swedish aircraft squadrons were in the range of 1 to 5 mg/m^3, but short-term peak exposures were as high as those measured for U.S. pilots. The Air Force Occupational Safety and Health (AFOSH) permissible exposure limit (PEL) for JP-4 is the same as that promulgated by the Occupational Safety and Health Administration (OSHA) for petroleum distillates (naphtha). The OSHA PEL for petroleum distillates is an 8-hour TWA of 400 ppm. Air Force regulations also include a 15-minute short-term exposure limit (STEL) of 500 ppm.

- **Persons living near military bases may be at risk for exposure from groundwater contamination due to spills or releases of jet fuels.**

In addition, persons at risk for jet fuel exposure may be exposed to high levels of tetraethyl lead, and persons who clean and maintain fuel cells and storage tanks may work in environments deficient in oxygen. Aircraft maintenance personnel often use solvents such as methyl ethyl ketone, methyl n-butyl ketone, or methyl isobutyl ketone, which may potentiate the neurologic effects of the n-hexane found in jet fuels.

Persons living near jet fuel manufacturing facilities, military bases, or hazardous waste sites may be exposed to JP-4 and JP-7 from spills, releases, or intentional dumping. These exposures may be from contaminated groundwater or from releases to air. Jet fuels are not used in consumer products.

* Because the composition of jet fuel is variable, a true molecular weight cannot be established. Without a molecular weight, the conversion of exposure concentrations from milligrams per cubic meter to parts per million is approximate.

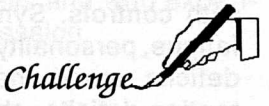
(2) Are other people in the case study at risk for exposure to jet fuel?

Biologic Fate

No data are available on how much JP-4 or JP-7 is absorbed by the dermal, inhalation, or oral routes. However, reports of neurologic effects after acute inhalation exposure to jet fuels confirm that they *are* absorbed by this route.

Several components of JP-4 and JP-7, such as benzene, xylene, and toluene, are known to be absorbed in humans by all routes. Interactions among the components of jet fuel may enhance or interfere with uptake or metabolism in unknown ways; therefore, no predictions can be made about the absorption or metabolism of JP-4 or JP-7 from characteristics of the individual components.

❑ **Some of the components of JP-4 and JP-7 are known to be systemically absorbed, but no information is available on the biologic fate of the fuels themselves.**



Additional information for the case study: A source at the base confirms that one of the aircraft jettisoned fuel at about the time the drops of liquid fell on the patient. An environmental official also confirms that a leak in an underground supply line has resulted in jet fuel contamination of the local water supply.

(3) The patient's husband asks you to test his wife to confirm that she has been exposed to jet fuel. What is your response?

Physiologic Effects

Acute exposure to jet fuel causes central nervous system (CNS) depression, but fatalities have not been reported. Little is known about the long-term effects of acute exposure to JP-4 or JP-7 in humans. Chronic exposure to JP-4 and related fuels has been associated with neuropsychiatric disorders and peripheral sensory neuropathy. JP-4 and JP-7 contain petroleum hydrocarbons that on contact may produce erythema, a burning sensation, and a defatting dermatitis. After prolonged contact, skin may become dry and peel, potentially enhancing future absorption.

Long-term studies of experimental animals exposed to high concentrations of JP-4 indicate decreased white blood cell counts and degenerative effects on the liver. No comparable human exposures have been reported.

Central Nervous System Effects

- **The central nervous system is the target of JP-4 toxicity in humans.**

Acute exposure to various jet fuels causes CNS depression and such CNS effects as dizziness, drowsiness, nausea, and vomiting. A pilot exposed to a fuel leak while in flight was reported to have subsequently experienced staggering gait, mild muscular weakness, and decreased sensitivity to pain; 36 hours after exposure, these effects were no longer evident.

- **Chronic exposure has been linked with neuropsychiatric disorders including anxiety, depression, memory deficits, and mood and personality changes.**

A group of 30 persons chronically exposed to 250 mg/m^3 of unspecified jet fuel in the course of manufacturing jet aircraft engines for periods of 4 to 32 years was reported to have a higher incidence of neuropsychiatric symptoms compared with controls. Symptoms included anxiety and depression, fatigue, personality changes, neurasthenic syndrome, memory deficits, mood changes, and psychosomatic symptoms. Attention deficits, changes in electroencephalograms, and reduction of sensorimotor speed were also seen in this group. Several epidemiologic studies of workers chronically exposed to jet fuel have reported various neurologic symptoms such as headache, dizziness, sleep disturbances, depression, anxiety, irritability, impairment of memory, and nausea. Similar effects probably occur with high-level exposures to JP-4 or JP-7.

In most occupational studies involving exposures to jet fuels, it is difficult to separate the effects of jet fuel from those of other substances such as carbon monoxide, which can also produce changes in the central nervous system and subjective symptoms similar to those reported for jet fuels. Few published studies of occupational exposures to jet fuels have

examined concurrent exposure to other hazards and their possible contribution to the reported effects.

Peripheral Nervous System Effects

Both JP-4 and JP-7 contain n-hexane, which is known to induce peripheral neuropathy after chronic exposure, especially with concomitant exposure to certain solvents such as methyl isobutyl ketone and methyl ethyl ketone. Workers exposed chronically to jet fuel in an aircraft factory were reported to have symptoms of polyneuropathy, including muscle cramps, "restless legs," pain, distal paresthesia and numbness, and paresis. The workers also had clinical signs such as lack of cutaneous and depth sensibilities, decreased motor functions, and possible hearing losses.

- **Chronic jet fuel exposure may cause peripheral sensory neuropathy.**

Hematologic Effects

No reports of possible effects of JP-4 or JP-7 on hematologic parameters have been reported in exposed humans. Leukopenia was reported in animal studies, possibly from the benzene in jet fuel.

Hepatic Effects

Jet aircraft fueling attendants were reported to have enhanced antipyrine clearance, suggesting that occupational exposure to jet fuel can cause enzyme induction in the liver. However, other laboratory tests of liver function were normal in this group, which suggests that jet fuel is not significantly hepatotoxic in humans. Liver function tests were normal in a group of 12 persons who were exposed to high levels of jet fuel during the course of cleaning fuel cells and who experienced signs and symptoms of CNS depression.

Respiratory Effects

Inhalation of jet fuel vapors may cause respiratory-tract irritation. Severe chemical pneumonitis, possibly with hemorrhagic pulmonary edema, has been produced by ingestion of other liquid petroleum products with subsequent vomiting and pulmonary aspiration of gastric contents. Ingestion usually occurs during attempts to siphon the liquids by mouth or from accidentally drinking the products.

- **Jet fuel vapors are irritating to the respiratory tract. Pulmonary aspiration after ingestion may cause pulmonary edema and possibly fatal chemical pneumonitis.**

Reproductive and Developmental Effects

- **Human reproductive and developmental risks of JP-4 and JP-7 are unknown.**

No studies that addressed reproductive outcomes in humans or experimental animals after exposure to jet fuel were found. Some of the components, such as benzene and toluene, are suspected human reproductive hazards. Whether these components in the complex formulation of JP-4 and JP-7 would have the same effects as the pure chemicals is not known. No data exist to conclude whether JP-4 or JP-7 can be transferred to the fetus or excreted in breast milk, although the highly lipophilic components may be. Hazards to the fetus or nursing infant caused by maternal exposure to jet fuel have not been determined.

Carcinogenic Effects

- **Some studies have suggested an association between jet fuel exposure and cancer in humans, but the evidence is not conclusive.**

The carcinogenic activity of JP-4 or JP-7 in humans is unknown. A statistically significant association between exposure to jet fuel and kidney cancer was reported in male cancer patients in Montreal, Canada. A weaker association with colorectal cancers has also been reported. The International Agency for Research on Cancer (IARC) has concluded that the evidence is inadequate to assess the carcinogenicity of jet fuel in humans or experimental animals.

Challenge

Additional information for the case study: Upon further questioning, you learn that the patient's hobby is restoring and painting antique furniture. She uses several products, such as paint thinner, that contain petroleum distillates. She also uses solvents for cleaning hardware.

(4) Could this information be important? Explain.

Clinical Evaluation

History and Physical Examination

The clinician should ask about previous occurrences of similar symptoms. A complete history should be obtained of possible occupational and environmental exposures to substances that can cause similar symptoms. Certain hobbies, such as painting, remodeling of houses, and furniture refinishing, can result in significant exposures to solvents and other petroleum products, some of which have the same components as jet fuel.

If a temporal association between symptoms and exposure to certain products is suspected, an attempt should be made to identify the specific chemical ingredients involved. If the product label does not list the chemical ingredients, a regional poison control center or the manufacturer can usually provide the ingredients in consumer products. In the workplace, the employer or manufacturer is required by law to provide a Material Safety Data Sheet (MSDS) for products, which lists the chemical ingredients and describes their potential toxicity. (See *Case Studies in Environmental Medicine: Taking an Exposure History.*)

Signs and Symptoms

Acute Exposure

Approximately half the persons occupationally exposed to jet fuel at a concentration of about 500 ppm reported signs of CNS depression, as well as symptoms of headache, nausea, and dizziness. Other reported symptoms include palpitations, chest pressure, and respiratory-tract irritation.

❑ **CNS effects, palpitations, and respiratory-tract irritation can occur after exposure to jet fuel.**

Although ingestion of jet fuel by humans has not been reported, ingestion with aspiration of the liquid into the lungs can be expected to cause coughing, dyspnea, tachypnea, rapidly developing pulmonary edema, and potentially fatal aspiration pneumonitis. Aspiration pneumonitis is associated with fever, leukocytosis, tachypnea, dyspnea, cyanosis, rhonchi, rales, and decreased breath sounds.

Chronic Exposure

Most reported chronic exposures to jet fuel appear to have been to high concentrations. Persons with chronic exposures have experienced fatigue, anxiety, memory impairment, personality and mood changes, neurasthenic syndrome, and other neuropsychiatric symptoms. Reported numbness or tingling in the extremities, especially in a glove-and-stocking pattern, *may* indicate a sensory peripheral neuropathy. No studies of chronic exposure to jet fuel were found in which exposures were characterized well enough to allow dose-response determinations.

❑ **Chronic exposure to jet fuel may cause CNS effects, although no dose-response relationship has been determined.**

Laboratory Tests

Direct Biologic Indicators

- **No specific biologic monitoring test exists for jet fuel.**

No direct method exists for determining exposure to jet fuel in biologic samples. Some individual components of these fuels (e.g., benzene) and their metabolites can be determined in blood and urine, but these tests are not specific for exposure to jet fuel.

Indirect Biologic Indicators

- **Standard clinical laboratory tests in persons exposed to jet fuel have usually been normal.**

If an exposure has been severe enough to cause CNS depression or loss of consciousness, consideration should be given to obtaining the following tests: CBC, SGOT (AST), SGPT (ALT), lactic dehydrogenase (LDH), bilirubin, alkaline phosphatase, BUN, creatinine, albumin, and urinalysis. A chest X ray and assessment of oxygenation (pulse oximetry or arterial blood-gas analysis) may be required in persons with respiratory-tract irritation or possible pulmonary aspiration.

- **Neuropsychologic tests may be difficult to interpret.**

Neuropsychologic testing may be useful for evaluating the conditions of persons who have functional changes after exposure. However, these tests are not specific for exposure to jet fuel.

Tests of nerve conduction velocity and sensory vibratory thresholds are used to detect peripheral nerve damage. The nerve conduction velocity test causes some discomfort and is performed only when signs and symptoms of peripheral neuropathy are present.

Challenge

(5) On the basis of her test results, what would you tell the patient about her symptoms? Could her symptoms have been due to the jet fuel exposure?

Treatment and Management

Acute Exposure

No specific treatment is available for acute exposure to jet fuel. Persons who have inhalation exposure should be removed from the contaminated environment, and oxygen should be administered if

signs of respiratory distress are present. Supportive care should be provided as indicated for persons who have signs of significant CNS depression. Persons who have moderate to severe exposure should be closely observed for at least 6 hours; they should be hospitalized if symptoms develop.

For cases of dermal exposure, all contaminated clothing should be removed immediately. Exposed skin and hair should be washed thoroughly with mild soap and shampoo, and rinsed thoroughly. Standard topical treatment may be required if skin irritation persists.

Exposed eyes should be irrigated with water or saline for at least 15 minutes. Ophthalmologic referral is advisable if pain persists or if photophobia, lacrimation, or swelling is present.

In cases of ingestion, gastric emptying is not indicated. Induced emesis or gastric lavage may increase the risk of aspiration and subsequent pneumonitis. The value of activated charcoal in treating patients who have ingested jet fuel is unknown. Because the administration of activated charcoal may cause emesis with subsequent pulmonary aspiration, this treatment should be reserved for very large ingestions.

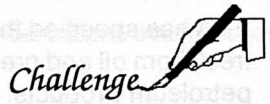
- **There is no antidote for jet fuel toxicity; supportive measures are required.**
- **Emptying the stomach is not indicated for ingestion of jet fuel; both induced emesis and gastric lavage entail some risk of aspiration and pneumonitis.**

Chronic Exposure

The most definitive determination that symptoms are caused by exposure to jet fuel is a temporal association between exposure and symptom development, with abatement of symptoms after exposure ceases. There is no specific treatment for chronic jet fuel toxicity. Most persons exposed to jet fuel appear to recover fully within several days after exposure is stopped. Neuropsychologic testing and a complete neurologic examination may be of use in patients who have persistent symptoms.

Dermal irritation should be treated with standard topical therapies.

- **Neuropsychologic effects are generally reversible after removal from exposure.**
- **A temporal association between exposure and symptoms is the best aid in diagnosing jet fuel toxicity.**



(6) What treatment would you recommend for the patient in the case study?

Standards and Regulations

Workplace

Air

- **U.S. Air Force and federal regulations for occupational exposure to jet fuel are based on exposure to petroleum distillates.**

Currently, the U.S. Air Force and OSHA designate a PEL for jet fuel based on the concentration of airborne aliphatic hydrocarbons. The PEL, which is the same as that for petroleum distillates (naphtha), is 400 ppm as an 8-hour TWA. The Air Force also designates an STEL of 500 ppm. The guideline suggested by the American Conference of Governmental Industrial Hygienists (ACGIH) is a threshold limit value (TLV) TWA of 300 ppm and a 15-minute STEL of 500 ppm, which is based on the TLV-TWA for gasoline. The NIOSH recommended exposure limit (REL) is 350 mg/m^3 (about 85 ppm) as an 8-hour TWA, with a 15-minute ceiling of 1800 mg/m^3 (about 438 ppm).

Persons who are occupationally exposed to jet fuel in the course of cleaning or maintaining fuel or storage tanks may also be exposed to oxygen-deficient atmospheres. OSHA has established a definition of an oxygen-deficient atmosphere at 19.5% oxygen; at levels below this, workers must wear supplied-air respirators or be withdrawn from the enclosure. A summary of current standards and regulations for jet fuels is given in Table 2.

Environment

Air

- **There are no environmental standards specific to jet fuel.**

Jet fuels are not regulated specifically as environmental air contaminants. As potential contributors to photochemical smog, their combustion products would be regulated by the Clean Air Act and local visibility, ozone, and carbon monoxide standards.

Water

- **Domestic water must be "virtually free" of oil and grease.**

EPA has specified that domestic water supplies must be "virtually free" from oil and grease, particularly from the tastes and odors of petroleum products. Oil and grease are also designated as conventional pollutants under the Clean Water Act. General pretreatment standards for new and existing point sources of waste streams must be followed to achieve effluent limitations for these contaminants as determined by measuring levels of polynuclear aromatic hydrocarbons.

Table 2. Standards and regulations for jet fuels

Agency*	Focus	Level	Comments
AFOSH	Air-workplace (as petroleum distillates [naphtha])	400 ppm 500 ppm	Regulation; TWA† STEL§
OSHA	Air-workplace (as petroleum distillates [naphtha])	400 ppm	Regulation; PEL¶
	Oxygen-deficient atmospheres	19.5%	Regulation
NIOSH	Air-workplace (naphtha)	350 mg/m^3 1800 mg/m^3	Guideline; REL** Ceiling††
ACGIH	Air–workplace (as gasoline)	300 ppm 500 ppm	Guideline; TLV§§ STEL
EPA	Water–environment (Domestic water supply)	"Virtually free"	Regulation
EPA	Water–environment (as oil and grease)	None	Regulation; Clean Water Act

*ACGIH = American Conference of Governmental Industrial Hygienists; AFOSH = Air Force Occupational Safety and Health; EPA = Environmental Protection Agency; NIOSH = National Institute for Occupational Safety and Health; OSHA = Occupational Safety and Health Administration

†TWA (time-weighted average) = time-weighted average concentration for a normal 8-hour workday and 40-hour workweek to which nearly all workers may be repeatedly exposed.

§STEL (short-term exposure limit) = TWA concentration determined by a short sampling period (usually 15 minutes) that should not be exceeded at any time during a workday.

¶PEL (permissible exposure limit) = TWA concentrations that must not be exceeded during any 8-hour workshift of a 40-hour workweek.

**REL (recommended exposure limit) = TWA concentration for up to a 10-hour workday during a 40-hour workweek.

††Ceiling = concentration that should not be exceeded at any time.

§§TLV (threshold limit value) = designation used by ACGIH to indicate 8-hour TWA concentrations.

Suggested Reading List

General

Davies NE. Jet fuel intoxication. Aerospace Med 1964; 35:481-2.

Knave B, Mindus P, Struwe G. Neurasthenic symptoms in workers occupationally exposed to jet fuel. Acta Psychiatr Scand 1979; 60:39-49.

Knave B, Olson BA, Elofsson S et al. Long-term exposure to jet fuel: Part II. A cross-sectional epidemiologic investigation on occupationally exposed industrial workers with special reference to the nervous system. Scand J Work Environ Health 1978; 4:19-45.

Knave B, Persson HE, Goldberg JM et al. Long-term exposure to jet fuel: an investigation on occupationally exposed workers with special reference to the nervous system. Scand J Work Environ Health 1976; 3:152-64.

Lombardi, AR, Lurie AS. Health hazards encountered in repair of jet aircraft fuel cells. JAMA 1957;164:531-3.

Reproductive Toxicity

Beliles RP, Mecler FJ. Inhalation teratology of Jet Fuel A, fuel oil and petroleum naphtha in rats. In: MacFarland HN, Holdsworth CE, MacGregor JA et al, eds. Proceedings of the symposium on toxicology of petroleum hydrocarbons. Washington, DC: American Petroleum Institute, 1982:233-8.

Carcinogenicity

International Agency for Research on Cancer (IARC). IARC monographs on the evaluation of carcinogenic risk of chemicals to humans: Occupational exposures in petroleum refining, crude oil and major petroleum fuels 1989;45:119-58, 203-18.

Siemiatycki J, Dewar R, Nadon L et al. Associations between several sites of cancer and twelve petroleum-derived liquids. Results from a case-referent study in Montreal. Scand J Work Environ Health 1987;13:493-504.

Related Government Documents

Agency for Toxic Substances and Disease Registry. Toxicological profile for jet fuels JP-4 and JP-7 (draft). Atlanta: US Department of Health and Human Services, Public Health Service, 1991.

Sources of Information

More information on the adverse effects of JP-4 or JP-7 and the treatment and managment of persons exposed to those substances can be obtained from ATSDR, your state and local health departments, poison control centers, and university medical centers. *Case Studies in Environmental Medicine: Jet Fuel Toxicity* is one of a series. To obtain other publications in this series, please use the order form on the inside back cover. For clinical inquiries, contact ATSDR, Division of Health Education, Office of the Director, at (404) 639-6204.

Answers to Pretest and Challenge Questions

Pretest

Pretest questions begin on page 1.

(a) The patient's problem list would consist of obesity, localized skin irritation, anxiety, fatigue, hypertension, possible peripheral neuropathy, and possible acute brain syndrome consisting of slightly impaired coordination and possible memory, behavioral, and mood changes.

(b) Some potential conditions that could explain the patient's problems include diabetes mellitus, hypothyroidism, anemia, meningitis or encephalitis, space-occupying intracranial lesions, stroke, and psychiatric disorders such as depression, anxiety, or personality disorder. The hypertension may be primary (essential) or secondary to anxiety, renal disease, pheochromacytoma, or Cushing's syndrome. The possible neurologic changes in the extremities could be due to diabetes. Fatigue could be caused by either diabetes or anemia. Early dementia, such as that caused by Alzheimer's disease, syphilis, lupus cerebritis, or HIV infection, are possibilities. Confusion may also be caused by chronic hypoxia.

(c) If the patient's blood glucose test result is high, a fasting glucose test should be scheduled and perhaps a glucose tolerance test. A CBC, urinalysis, BUN, serum creatinine, liver function tests, thyroid-stimulating hormone (TSH), erythrocyte sedimentation rate (ESR), syphilis test (VDRL), and pulse oximetry may be useful to exclude possible conditions. To evaluate the neurologic complaints, neurologic testing could be performed. Cerebral-imaging tests (e.g., computerized tomography or magnetic resonance imaging) may be used to rule out brain tumor or structural degenerative changes in the brain. Nerve conduction velocity tests can be used to confirm peripheral neuropathy. Neuropsychologic tests might include tests of short- and long-term memory and information processing and a Minnesota Multiphasic Personality Inventory (MMPI). Other clinical tests may be required to exclude other possible diagnoses of the psychologic effects.

(d) Once preexisting disease has been determined or excluded, contamination of the air and water in the patient's home by jet fuel is still a possibility. The water should be tested. Ambient air exposures during activities that use hot water may be significant because of the volatility of jet fuel. The patient should be removed from these exposures and from exposure to similar petroleum products and solvents. She should then be monitored to determine if her symptoms abate. If the water supply is contaminated, an alternate source of cooking, drinking, and other water uses should be supplied.

Challenge

Challenge questions begin on page 5.

(1) You should notify the Air Force Base and the local and state health departments about the possible groundwater contamination and request that chemical analyses be performed on the water to determine if the profile of contaminants is consistent with that of JP-4 or JP-7. It may be advisable to quantify benzene and n-hexane if the water is contaminated by jet fuel. If the water is contaminated, air levels could be determined in the house under conditions likely to volatilize the contaminants. Personal exposures could then be estimated and compared to levels of jet fuel known to produce adverse effects. There is no definitive diagnostic test for JP-4 or JP-7 toxicity.

(2) Yes. The neighbors should be interviewed by the health department and examined by physicians for similar symptoms. They could have been exposed during the same jettisoning operation as well as from the groundwater. The patient's husband works as an aircraft mechanic. He could be exposed at work, and the patient could be exposed by handling his work clothes.

(3) There are no specific clinical or chemical tests to confirm exposure to jet fuel. Some of the components can be detected in the blood or urine, but their presence would not necessarily be due to jet fuel. Clinical evidence for exposure is circumstantial, with the strongest link being a temporal association between acute exposure

Answers to Pretest and Challenge Questions continued

to the suspected agent and development of signs and symptoms. Chemical analysis of the soil from the backyard where the jettisoned fuel landed, along with analyses of the drinking water supply, most likely would provide the best evidence of exposure.

(4) You should determine whether the patient has ever experienced similar symptoms during or after use of these products. Obtain the labels of the products; if ingredients are not listed, contact a regional poison control center or the manufacturer. Of special concern are petroleum distillates and methyl isobutyl ketone and methyl ethyl ketone, which may exacerbate peripheral neuropathy caused by n-hexane. Lead and arsenic may also cause peripheral neuropathy.

(5) The patient's symptoms are consistent with those caused by jet fuel. If jet fuel exposure is the source, her symptoms should resolve within several days after removal from further exposure. If her symptoms continue, further testing will be needed to rule out other possible causes and to better characterize the nature of her neuropsychologic symptoms.

(6) See Pretest answer (d) above.

Posttest and Credits

Continuing education credit is available to health professionals who use this monograph and complete the posttest. The criterion for awarding continuing medical education (CME) credits and continuing education units (CEU) is a posttest score of 70% or better.

The Centers for Disease Control and Prevention (CDC) is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to sponsor continuing medical education for physicians, and by the International Association for Continuing Education and Training (IACET) to sponsor continuing education units for other health professionals.

The Agency for Toxic Substances and Disease Registry, in joint sponsorship with CDC, is offering 1 hour of CME credit in Category 1 of the Physician's Recognition Award of the American Medical Association and 0.1 hour of CEU for other health professionals upon completion of this monograph.

In addition, the series *Case Studies in Environmental Medicine* has been reviewed and is acceptable for credit by the following organizations:

The **American Academy of Family Physicians (AAFP)**. This program has been reviewed and is acceptable for 1 prescribed hour by the American Academy of Family Physicians. (Term of Approval: beginning January 1992.) For specific information, please consult the AAFP Office of Continuing Medical Education.

The **American College of Emergency Physicians (ACEP)**. Approved by the American College of Emergency Physicians for one hour per issue of ACEP Category I credit.

The **American Osteopathic Association (AOA)**. AOA has approved this issue for 1 credit hour of Category 2-B credit.

The **American Association of Occupational Health Nurses (AAOHN)**. AAOHN has approved this program for 1.0 contact hours. Applicant will receive the assigned code number in the award letter.

The **American Board of Industrial Hygiene (ABIH)**. ABIH has approved this program for 0.5 certification maintenance (CM) point per 3 Case Studies. The CM approval number is 2817.

To receive continuing education credit (CME or CEU), complete the Posttest on page 20 in the manner shown in the sample question below. **Circle all correct answers.**

Which of the following is known to precipitate migraine headaches?

(a) fatigue
(b) alcohol
c. grapefruit
(d) sunlight
e. sleep

After you have finished the Posttest, please transfer your answers to the answer sheet on the inside back cover and complete the evaluation on the lower half of that page. Fold, staple, and mail the back cover to Continuing Education Coordinator, Agency for Toxic Substances and Disease Registry, Division of Health Education, E33, 1600 Clifton Road, Atlanta, GA 30333. Your confidential test score will be returned with an indication of where the correct answers can be found in the text. Validation of earned CME credit and CEU will also be forwarded to participants, and their names, if requested, will be placed on the mailing list to receive other issues in the *Case Studies in Environmental Medicine* series.

POSTTEST: JET FUEL

Circle **all** correct answers. Record your answers on page 21.

1. Significant exposure to JP-4 or JP-7 may occur from
   a. consumer products
   b. eating produce grown in soil irrigated by contaminated water
   c. manufacture of jet engines
   d. eating contaminated fish
   e. contaminated water in the vicinity of military bases

2. Which of the following is known to occur with JP-4?
   a. It can remain for years in contaminated soil.
   b. It has been shown to contaminate groundwater near spills.
   c. It evaporates slowly from surface water.
   d. It contributes to the depletion of the ozone layer.
   e. It cannot be degraded biologically.

3. Which of the following statement(s) is (are) false concerning jet fuel?
   a. IARC classifies JP-4 as a known human carcinogen.
   b. Hepatic effects seen in animals do not occur in humans.
   c. A sensitive indicator of exposure in humans is a retinol-binding protein test.
   d. JP-7 is known to cause birth defects in humans.
   e. Chest X ray may be required after inhalation or ingestion exposure.

4. Which of the following symptoms have been reported in humans from *acute* exposure to jet fuel?
   a. hemolytic anemia
   b. neuropsychiatric disorders
   c. pulmonary edema
   d. polyneuropathy
   e. CNS depression

5. Chronic exposure to JP-4 or JP-7 may produce
   a. hemolytic anemia
   b. personality changes
   c. auditory dysfunction
   d. hormonal abnormalities
   e. anxiety

6. Useful intervention(s) for patients who have acute inhalation of jet fuel include(s)
   a. methylene blue therapy
   b. supportive oxygen
   c. monitoring blood gases
   d. carboxyhemoglobin determination
   e. hemoperfusion or hemodialysis

7. Possible treatment(s) for a large ingestion of jet fuel include(s)
   a. routine induction of emesis
   b. activated charcoal
   c. hemoperfusion or hemodialysis
   d. chest X ray
   e. corticosteroids

8. The differential diagnosis for symptoms produced by acute exposure to jet fuel might include
   a. heat stroke
   b. diabetes mellitus
   c. hypothyroidism
   d. Alzheimer's disease
   e. structural intracranial lesion

CASE STUDIES IN ENVIRONMENTAL MEDICINE: JET FUEL TOXICITY

If you wish CME credits or CEU, please indicate your answers to the Posttest questions on page 20 by circling the letters below for the correct answers. Complete the evaluation questionnaire and fill in the information requested on the reverse side. Tear off this last page, fold, staple, and mail to Continuing Education Coordinator, Agency for Toxic Substances and Disease Registry, Division of Health Education, E33, 1600 Clifton Road, Atlanta, GA 30333.

1. a b c d e
2. a b c d e
3. a b c d e
4. a b c d e
5. a b c d e
6. a b c d e
7. a b c d e
8. a b c d e

Evaluation Questionnaire

Please complete the following evaluation by putting a check in the appropriate box.

	Yes	No	Undecided
1. As a result of completing this monograph, I will be able to:			
Explain why JP-4 and JP-7 may be acute and chronic health hazards.	☐	☐	☐
Describe the factors that may contribute to poisoning by JP-4 and JP-7.	☐	☐	☐
Identify potential environmental and occupational sources of exposure to JP-4 and JP-7.	☐	☐	☐
Identify evaluation and treatment protocols for persons exposed to JP-4 and JP-7.	☐	☐	☐
List sources of information on JP-4 and JP-7.	☐	☐	☐
2. I am more likely to ask patients questions regarding possible environmental exposures as a result of reading this issue.	☐	☐	☐
3. I would recommend this issue to my colleagues.	☐	☐	☐
4. I will keep this issue as a reference.	☐	☐	☐

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Please send me the following *Case Studies in Environmental Medicine.*

- ☐ Arsenic
- ☐ Asbestos
- ☐ Benzene
- ☐ Beryllium
- ☐ Cadmium
- ☐ Carbon Tetrachloride
- ☐ Chlordane
- ☐ Cholinesterase Inhibitors
- ☐ Chromium
- ☐ Cyanide
- ☐ Dioxins
- ☐ Ethylene/Propylene Glycols
- ☐ Exposure History
- ☐ Gasoline
- ☐ Jet Fuel
- ☐ Lead
- ☐ Mercury
- ☐ Methanol
- ☐ Methylene Chloride
- ☐ Nitrates/Nitrites
- ☐ Pentachlorophenol
- ☐ Polyaromatic Hydrocarbons (PAHs)
- ☐ Polychlorinated Biphenyls (PCBs)
- ☐ Radiation
- ☐ Radon
- ☐ Risk Communication
- ☐ Reproductive and Developmental Hazards
- ☐ Skin Lesions
- ☐ Stoddard Solvent
- ☐ Tetrachloroethylene
- ☐ 1,1,1-Trichloroethane
- ☐ Trichloroethylene
- ☐ Toluene
- ☐ Vinyl Chloride

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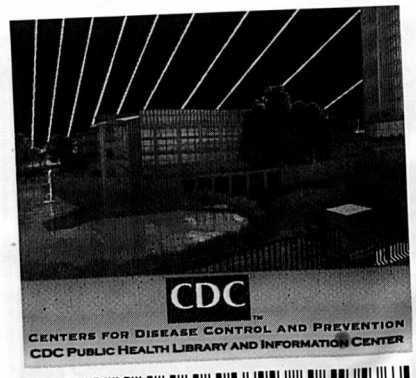
staple or tape



The state of knowledge regarding the treatment of patients potentially exposed to hazardous substances in the environment is constantly evolving and is often uncertain. In this monograph, the Agency for Toxic Substances and Disease Registry (ATSDR) has made diligent effort to ensure the accuracy and currency of the information presented but makes no claim that the document comprehensively addresses all possible situations related to this substance. This monograph is intended as an additional resource for physicians and other health professionals in assessing the condition and managing the treatment of patients potentially exposed to hazardous substances. It is not, however, a substitute for the professional judgment of a health care provider and must be interpreted in light of specific information regarding the patient available to such a professional and in conjunction with other sources of authority.

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