VDH VIRGINIA DEPARTMENT OF HEALTH
Protecting You and Your Environment

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FUEL OILS

GENERAL

Fuel oils are derived from crude petroleum and are complex mixtures primarily of aliphatic (64%), aromatic (35%), and olefinic (1-2%) hydrocarbons. In addition, they may contain small amounts of sulfur, oxygen, nitrogen compounds, and other substances as additives. Crude petroleum is found widely distributed over the surface of the earth, generally in sands saturated with oil and trapped under the surface by overlying geological strata. Fuel oils are distinguished from each other based primarily on their boiling point ranges, chemical additives, and uses. All fuel oils are liquid at room temperature and they can evaporate. Great variations between batches of fuel oils exist because of the differences in the ratios of aliphatic, aromatic, and olefinic hydrocarbons in the crude petroleum. Most fuel oils are yellowish to light brown in color. They generally have a kerosene-like smell, are flammable, and burn at temperatures between 177°C and 329°C.

In this fact sheet, six types of fuel oils are discussed together because they have similar chemical and physical properties. These are presented below in Table 1.

Table 1. Chemical Identity of Fuel Oils

Chemical Name	**Fuel Oil #1**	**Fuel Oil #1-D**	**Fuel Oil #2**	**Fuel Oil #2-D**	**Fuel Oil #4**	**Fuel Oil UNSP**
CAS registry	8008-20-6 70892-10-3	No data	68476-30-2	68476-34-6	68476-31-3	No data
Synonym(s)	Kerosene; coal oil; kerosine; range oil; straight run kerosene; distillate fuel oils, light; furnace oil #1; Deobase; JP-5 (jet fuel); JP-1	Diesel fuel; diesel fuel oil #1; diesel oil #1; #1 diesel; diesel oil (light); Arctic diesel	API no. 2 fuel oil; gas oil; home heating oil #2; #2 burner oil; furnace oil #2	Diesel fuel #2; diesel fuel oil #2; diesel oil #2; #2 diesel; diesel oil (medium)	Oil, fuel #4; residual fuel oil #4; #4 fuel oil; residual fuel oil; marine boiler fuel; marine diesel fuel; diesel fuel #4; grade 4	None

All of the fuel oil classes discussed above are refined from crude petroleum and may be categorized as either a distillate fuel or a residual fuel depending on the method of production. Fuel oils #1 & #2 are distillate fuels which consist of distilled process streams. Residual fuel oils, such as fuel oil #4, are the residues remaining after distillation. Diesel fuels are generally similar to fuel oils used for heating (fuel oils #1 & #2, and #4). Fuel oil #1 is a light distillate which consists primarily of hydrocarbons in the C_9-C_{16} range; fuel oil #2 is a heavier, usually blended, distillate with hydrocarbons in the C_{11}-C_{20} range. Diesel fuel #1-D and #2-D are similar in chemical composition to fuel oil #1 and #2, respectively, with the exception of the additives. Diesel fuels predominantly contain a mixture of C_{10} through C_{19} hydrocarbons. Fuel oil #4 is less volatile than diesel fuel #2-D. Residual fuel oils are generally more complex in composition and impurities than distillate fuel oils.

USES

Fuel oils are used primarily as heating oils, in many types of internal-combustion engines, and as solvents. Fuel oil #1 is used for domestic heating and as a vehicle for pesticides. Fuel oil #1 is also used in kerosene lamps, flares, and stoves. Fuel oil #2 has been used as a home heating oil and as an industrial heating oil. Fuel oil #1-D is used in engines that require frequent load and speed changes. Fuel oil #2-D has been used for engines that are in industrial or heavy mobile service. Fuel oil #4 has been used to process steam for electric plants, for space and water heating, pipeline pumping, and gas compression.

HEALTH EFFECTS

Acute Effects

Most of the information on human exposure comes from cases of ingestion of kerosene that resulted in respiratory, neurotoxic, and gastrointestinal effects. In addition, a few case studies have identified these effects, as well as cardiovascular, hematological, and renal effects in humans by inhalation and/or dermal exposures to fuel oils. Fuel oils appear to be eye and skin irritants in both humans and animals following direct contact. Two case studies reported mild hypertension in humans following acute inhalation exposures to fuel oils. Mild hypertension and gastrointestinal effects were noted for 4 days. One case study describes eye irritation in two individuals exposed to Jet Propulsion Fuel #5 (JP-5) vapors for approximately 1 hour while flying a small airplane. Both individuals experienced a burning sensation in their eyes and one had itchy, watery eyes one day after the exposure. These eye effects subsided within 24 hours. Another case study describes subconjunctival hemorrhages in a man who had washed his hair with an unknown amount of diesel fuel. Eye and throat irritations were not induced in six volunteers by a 15-minute exposure to 140 milligrams per cubic meter of air (mg/m^3) deodorized kerosene. This study is limited since only one concentration was tested. The estimated oral lethal dose of kerosene for 1-2 year old children ranges from 1,890 to 16,789 milligrams/kilogram per day (mg/kg/day).

Fuel oil #2-D has a low order of acute oral and dermal toxicity. The acute oral LD_{50} for rats is greater than 5 grams per kilogram (g/kg) and acute dermal LD_{50} for rabbits is greater than 3.16 g/kg. The acute oral LD_{50} values in guinea pigs and rabbits for kerosene have been reported to be 16,320 mg/kg/day and 22,720 mg/kg/day, respectively. A lethal dose of kerosene of 6,400 mg/kg/day has been reported in calves. Acute lethal doses in rats were reported to be 12,000 mg/kg/day for kerosene and 47,280 mg/kg/day for JP-5. A lethal dose of 30,000 mg/kg/day was reported for JP-5 from acute dermal exposure in mice. A single 6-hour exposure to 4,000 mg/m^3 diesel fuel aerosol was lethal to rats. Mortality occurred in 3 of 10 mice exposed by acute inhalation to diesel fuel #2-D vapors at a concentration of 204 mg/m^3; inhalation of 65 or 135 mg/m^3 was not lethal to mice. No lethality occurred following single exposure inhalations of 6,000 mg/m^3 diesel fuel aerosol for 4 hours or 2,700 mg/m^3 for 6 hours. There were no mortalities in rats exposed to 5,000 mg/m^3 kerosene vapors for 4 hours. The odor threshold for kerosene vapors has been estimated to be about 0.5 mg/m^3.

Chronic Effects

An epidemiological study tested the effects of chronic exposure to jet fuels in factory workers. This study found a significant increase in the stated symptom of a feeling of heaviness in the chests of exposed subjects when compared to unexposed controls from the same factory. Eye irritation was also noted in this study. The limited epidemiological information that exists for humans indicates that chronic inhalation exposure to kerosene does not cause respiratory toxicity, although chronic dermal exposure does cause dermatosis.

Neurological Effects

Many neurological effects were reported from kerosene ingestion by children. The reported signs and symptoms included unconsciousness or semiconsciousness, drowsiness, restlessness, irritability, and in a few cases, coma and convulsions. Neither coma nor convulsions occurred in children that ingested 3-20 milliliters (ml) of kerosene. This dose is equivalent to a range of 126 to 1,754 mg/kg/day in children aged 10 months to 5 years. Severe headaches occurred in individuals exposed to diesel fuel for 10 days. Anorexia occurred in a man following dermal and/or inhalation exposure to diesel fuel over several weeks. Other neurological effects were reported following inhalation of JP-5 vapors in two individuals who had fatigue, coordination, and concentration difficulties. Effects subsided within 24 hours for one individual and within 4 days for the other. Sensory impairment did not occur in these individuals. However, experimental data indicate that olfactory fatigue and taste sensation may occur in some individuals after a 15-minute inhalation exposure of 140 mg/m^3 deodorized kerosene. Neurasthenia (i.e., fatigue, depressed mood, lack of initiative, dizziness, and sleep disturbances) and impairment of attention and sensorimotor speed were associated with chronic inhalation, oral, and/or dermal exposures to jet fuel by factory workers.

Acute inhalation of diesel fuel #2-D induced dose-dependent ataxia, increased sensitivity to heat, changes in behavior, and tremors in mice. Oral exposure to kerosene induced ataxia and drowsiness in rats. Aspiration of kerosene induced drowsiness, lack of muscular coordination, and behavior changes, while dermal exposure induced an increased response to tactile stimuli and hyperactivity in mice. No histopathologic changes were noted in the nervous system of mice following dermal exposure to JP-5 or marine diesel fuel. The risk of neurological effects from inhalation exposure is increased if exposures occur in confined spaces.

Reproductive Effects

No studies were found regarding reproductive toxicity in humans from inhalation, oral, or dermal exposure to fuel oils. There were no pathological changes in the reproductive organs of mice following chronic and/or intermediate dermal exposures to marine diesel fuel or JP-5, or in rats following intermediate inhalation of diesel fuel aerosol.

Developmental Effects

No studies were found regarding developmental toxicity in humans from inhalation, oral, or dermal exposures to fuel oils. Several studies were identified that tested developmental effects in animals, but only using the inhalation route of exposure. These studies found no developmental effects in the fetuses or female rats that had been exposed to heating oil, fuel oil, UNSP, or diesel fuel vapors by inhalation during gestation days 6-15.

Immunological Effects

No information was found regarding immunotoxicity in humans from inhalation, oral, or dermal exposure to fuel oils. Only two animal studies were identified that tested immunological effects, both using mice. These studies identified cellular effects in the bone marrow, lymph nodes, and/or thymus, and decreases in the relative weights of the lymph nodes and thymus resulting from acute dermal exposures to kerosene and chronic dermal exposures to JP-5 and marine diesel fuels.

Mutagenic Effects

Inhalation of 100 and 400 ppm diesel fuel, 6 hours/day, 5 days/week, for 8 weeks produced no adverse effects with respect to fertility or the frequency of dominant lethal mutations in male CD-1 mice (12/group). Diesel fuel was classified as positive in the rat bone marrow cytogenic assay when either single or multiple (5 consecutive days) intraperitoneal injections of 0.6, 2.0, or 6.0 mg/kg diesel fuel were administered. Kerosene was mutagenic in Salmonella typhimurium TA98 assays. However, neither marine diesel fuel nor JP-5 was mutagenic in Salmonella typhimurium preincubation assays.

Carcinogenicity

Cancer data in humans from epidemiological studies did not find an association between cancer and exposure to fuel oils. No dermal cancer was noted in B6C3F1 mice following chronic dermal exposures to 250 or 500 mg/kg/day of JP-5. However, unspecified skin tumors were noted in C3HF/Bd mice, but the tumors were not dose related under most exposure conditions. There was an increased incidence of squamous cell papilloma and/or carcinoma in mice chronically exposed to 250 or 500 mg/kg/day marine diesel fuel after dermal exposure. Hepatocellular adenoma or carcinoma were noted in male, but not in female, mice exposed to 250 or 500 mg/kg/day marine diesel fuel after dermal exposure. The incidence of malignant lymphomas was not dose related in females exposed to JP-5.

EPA has classified some of the heavy aromatics in fuel oils as probable human carcinogens.

ENVIRONMENTAL EFFECTS

Fuel oils may be released to surface waters, soils, and air as a result of accidental spills during use or transportation or from leaking underground storage facilities or pipelines. The more volatile components of fuel oils (low molecular weight alkanes) evaporate from the water or soil and enter the atmosphere where they are degraded. The high molecular weight aliphatic components have very low water solubility and will not volatilize from soils or surface waters. Consequently, these heavier components will remain on the soil or in the water column where they may be adsorbed to particulate organic matter or settle to the sediment. They will eventually be biodegraded by microorganisms in the soils and sediments. The rate and extent of biodegradation are dependent on the ambient temperature, the presence of a sufficient number or microorganisms capable of degrading these hydrocarbons, and the concentration of fuel oil in or on the soil or water. Aromatic components are most susceptible to biodegradation in warm water or soil, although some volatilization may occur in colder waters. Aromatics, however, are also water soluble and therefore are the most likely fuel oil components to leach through soil into groundwater.

STANDARDS AND GUIDELINES

The Occupational Safety and Health Administration (OSHA) has established the permissible exposure limit (PEL) of 400 parts per million ($\approx$1600 mg/m^3) of petroleum distillates (naphtha) in the workplace air. The limit is based on an eight-hour, time-weighted average for a 40-hour work week.

Fuel oils are designated as hazardous materials, which are subject to requirements for packaging, shipping, and transporting under the Hazardous Materials Transportation Act of the Department of Transportation (DOT).

Oils and grease are designated as conventional pollutants. Effluent limitations for oils and grease exist for almost all point sources under the general pretreatment standards for new and existing sources under the Clean Water Act.

The U.S. Congress adopted the Oil Pollution Act of 1990, 33 U.S.C. Section 2701 et seq., in the wake of the Valdez oil spill in Prince William Sound, Alaska, in order to impose stricter prevention standards and much higher clean-up costs and penalties on owners and operators of vessels and facilities handling, storing, or transporting oil. Liability for clean-up of a spill is capped at $350 million plus interest.

In Maine, drinking water quality guidelines for fuel oil #2 in community water systems is 100 micrograms per liter (µg/ℓ).

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