POLLUTION CONTROL & SAFETY

Summary: Exposure to toluene happens mostly through breathing contaminated workplace air or automobile exhaust, or during deliberate glue sniffing or solvent abuse. Breathing high levels of toluene affects the brain and can cause headaches, confusion, dizziness, sleepiness, and memory loss. Toluene has been found in at least 869 of 1,416 National Priorities List sites identified by the EPA.

Toluene is a clear colorless liquid with a sweet smell . It occurs naturally in crude oil and in the tolu tree. It is produced for commercial use in the process of making gasoline and other fuels from crude oil; in the making of coke from coal; and as a by-product in the manufacture of styrene. Toluene is used to manufacture paints, paint thinners, nail polish, laquers, certain chemicals, adhesives, rubber, and in some printing and leather tanning processes.

This summary is based on information retrieved from a systematic search limited to secondary sources .These sourcesinclude online databases, unpublished EPA information, government publications, review documents, and standard reference materials. Noattempt has been made to verify information in these databases and secondary sources.

I) ENVIRONMENTAL FATE

A. Environmental Release

Of the total toluene released to the environment almost all is released to the air.Toluene is a volatile liquid [vapor pressure, 22 mm Hg at 20øC (Verschueren 1983)], and is released into the atmosphere from industrial and consumer uses.The largest sources of toluene release are the evaporation from gasoline, which is 5-7% toluene, and release through car exhausts. Spills of gasoline and industrial releases to surface water and soil are believed to be only a small fraction of the amount released to the atmosphere (ATSDR 1993). In 1992 releases of toluene to environmental media, as reported to the Toxic Chemical Release Inventory by certain types of U.S. industries totaled about 193 million pounds. Of this amount, a total of 191 million pounds (99%) were released to the

atmosphere, 84 thousand pounds were released to surface water, 1.6 million pounds were released to underground injection sites, and 708 thousand pounds were released to land (TRI92 1994). vels of toluene in environmental media range from 1-30 micro-grams/m3 in suburban and urban air and 0.1-2.9 micrograms/L in rinking water. Toluene contamination was detected in a maximum of only about 1.2% of the underground water supplies tested, however. The maximum air concentrations of toluene are found indoors and in one study ranged from 37.8 to 71.1 micrograms/m3.The increased concentration compared to urban outside air could originate from household products such as paints, thinners, glue, infiltration from auto emissions, and from cigarette smoke. Cigarettes contain about 80 micrograms toluene/cigarette (ATSDR 1993).

B. Transport:

The majority of toluene evaporates to the atmosphere from the water and soil.It is moderately retarded by adsorption to soils rich in organic material (Koc = 259), therefore, transport to ground water is dependent on the soil composition (ATSDR 1993). In unsaturated topsoil containing organic material, it has been estimated that 97% of the toluene is adsorbed to the soil and only about 2% is in the soil-water phase and transported with flowing groundwater. There is little retardation in sandy soils and 2-13% of the toluene was estimated to migrate with flowing water; the remainder was volatilized, biodegraded, or unaccounted for. In saturated deep soils with no soil-air phase, about 48% may be transported with flowing groundwater (U.S. Air Force 1989).

C. Transformation/Persistence

1. Air - The main degradation pathway for toluene in the atmosphere is reaction with photochemically produced hydroxyl radicals. The estimated atmospheric half life for toluene is about 13 hours. Toluene is also oxidized by reactions with atmospheric nitrogen dioxide, oxygen, and ozone, but these are minor degradation pathways. Photolysis is not considered a significant degradative pathway for toluene (ATSDR 1993).

2. Soil - In surface soil, volatilization to air is an important fate process for toluene (U.S. Air Force 1993). Biodegradation of toluene has been demonstrated in the laboratory to

occur with a half life of about 1 hour. In the environment, biodegradation of toluene to carbon dioxide occurs with a typical half life of 1-7 days (ATSDR 1993).

3. Water - An important fate process for toluene is volatilization, the rate of which depends on the amount of turbulence in the surface water (ATSDR 1993).The volatilization of toluene from static water has a half life of 1-16 days, whereas from turbulent water the half life is 5-6 hours. Degradation of toluene in surface water occurs primarily by biodegradation with a half life of less than one day under favorable conditions (presence of microorganisms, microbial adaptation, and optimum temperature). Biodegradation also occurs in shallow groundwater and in salt water at a reduced rate (ATSDR 1993). No data are available on anaerobic degradation of toluene in deep ground water conditions where aerobic degradation would be minimal (ATSDR 1993).

4. Biota - Bioaccumulation in most organisms is limited by the metabolism of toluene into more polar compounds that have greater water solubility and a lower affinity for lipids. Bioaccumulation in the food chain is predicted to be low (ATSDR 1993; U.S. EPA 1990).

II. HUMAN HEALTH EFFECTS

A. Pharmacokinetics

1. Absorption - Studies in humans and animals have demonstrated that toluene is readily absorbed via the lungs and the gastrointestinal tract. Absorption through the skin is estimated at about 1% of that absorbed by the lungs when exposed to toluene vapor. Dermal absorption is expected to be higher upon exposure to the liquid; however, exposure is limited by the rapid evaporation of toluene (Faust 1994).

2. Distribution - In studies with mice exposed to radiolabeled toluene by inhalation, high levels of radioactivity were present in body fat, bone marrow, spinal nerves, spinal cord, and brain white matter. Lower levels of radioactivity were present in blood, kidney, and liver. Accumulation of toluene has generally been found in adipose tissue, other tissues with high fat content, and in highly vascularized tissues (Faust 1994).

3. Metabolism - The metabolites of inhaled or ingested toluene include benzyl alcohol resulting from the hydroxylation of the methyl group. Further oxidation results in the

formation of benzaldehyde and benzoic acid. The latter is conjugated with glycine to yield hippuric acid or reacted with glucuronic acid to form benzoyl glucuronide. o-cresol and p-cresol formed by ring hydroxylation are considered minor metabolites (Faust 1994).

4. Excretion - Toluene is primarily (60-70%) excreted through the urine as hippuric acid. The excretion of benzoyl glucuronide accounts for 10-20%, and excretion of unchanged toluene through the lungs also accounts for 10-20%. Excretion of hippuric acid is usually complete within 24 hours after exposure (U.S. EPA 1990).

B. Acute Toxicity

Humans exposed to intermediate to high levels of toluene for short periods of time experience adverse central nervous system effects ranging from headaches to intoxication, convulsions, narcosis, and death. Similar effects are observed in short-term animal studies.

1. Humans - Toluene ingestion or inhalation can result in severe central nervous system depression, and in large doses, can act as a narcotic. The ingestion of about 60 mL resulted in fatal nervous system depression within 30 minutes in one reported case. Constriction and necrosis of myocardial fibers, markedly swollen liver, congestion and hemorrhage of the lungs and acute tubular necrosis were found on autopsy (Faust 1994).

Central nervous system effects (headaches, dizziness, intox-ication) and eye irritation occurred following inhalation exposure to 100 ppm toluene 6 hours/day for 4 days. Exposure to 600 ppm for 8 hours resulted in the same and more serious symptoms including euphoria, dilated pupils, convulsions, and nausea (U.S. EPA 1994). Exposure to 10,000-30,000 ppm has been reported to cause narcosis and death (U.S. Air Force 1989). Toluene can also strip the skin of lipids causing dermatitis

2. Animals - The initial effects are instability and incoordination, lacrimation and sniffles (respiratory exposure), followed by narcosis. Animals die of respiratory failure from severe nervous system depression. Cloudy swelling of the kidneys was

reported in rats following inhalation exposure to 1600 ppm, 18-20 hours/day for 3 days (U.S. EPA 1990).

C. Subchronic/Chronic Effects

Repeat doses of toluene cause adverse central nervous system effects and can damage the upper respiratory system, the liver, and the kidney. Adverse effects occur as a result from both oral and the inhalation exposures. A reported lowest-observed-effect level in humans for adverse neurobehavioral effects is 88 ppm. EPA has derived both an oral RfD (0.2 mg/kg/day) and an inhalation RfC (0.4 mg/m3) for toluene exposures.

1. Humans - Chronic occupational exposure and incidences of toluene abuse have resulted in hepatomegaly and liver function changes. It has also resulted in nephrotoxicity and, in one case, was a cardiac sensitizer and fatal cardiotoxin.

Neural and cerebellar dystrophy were reported in several cases of habitual "glue sniffing." An epidemiological study in France on workers chronically exposed to toluene fumes reported leukopenia and neutropenia. Exposure levels were not given in the secondary reference; however, the average urinary excretion of hippuric acid, a metabolite of toluene, was given as 4 g/L compared to a normal level of 0.6 g/L (Sandmeyer 1989).

2. Animals - The major target organs for the subchronic/chronic toxicity of toluene are the nervous system, liver, and kidney. Depressed immune response has been reported in male mice given doses of 105 mg/kg/day for 28 days (Faust 1994). Toluene in corn oil adminisered to F344 male and female rats by gavage 5 days/week for 13 weeks, induced prostration, hypoactivity, ataxia, piloerection, lacrimation, excess salivation, and body tremors at doses ò2500 mg/kg. Liver, kidney, and heart weights were also increased at this dose and histopathologic lesions were seen in the liver, kidneys, brain and urinary bladder. The no-observed-adverse effect level (NOAEL) for the study was 312 mg/kg (223 mg/kg/day) and the lowest-observed-adverse effect level (LOAEL) for the study was 625 mg/kg (446 mg/kg/day) (U.S. EPA 1994). Based on these data, the U.S. EPA (1994) calculated a chronic RfD (reference dose) for toluene of 0.2 mg/kg/day.

D. Developmental/Reproductive Toxicity

Exposures to high levels of toluene can result in adverse effects in the developing human fetus. Several studies have indicated that high levels of toluene can also adversely effect the developing offspring in laboratory animals.

1. Humans - Variable growth, microcephaly, CNS dysfunction, attentional deficits, minor craniofacial and limb abnormal- ities, and developmental delay were seen in three children exposed to toluene in utero as a result of maternal solvent abuse before and during pregnancy

2. Animals - Sternebral alterations, extra ribs, and missing tails were reported following treatment of rats with 1500 mg/m3 toluene 24 hours/day during days 9-14 of gestation. Two of the dams died during the exposure. Another group of rats received 1000 mg/m3 8 hours/day during days 1-21 of gestation. No maternal deaths or toxicity occurred, however, minor skeletal retardation was present in the exposed fetuses. CFLP Mice were exposed to 500 or 1500 mg/m3 toluene continuously during days 6-13 of pregnancy. All dams died at the high dose during the first 24 hours of exposure, however none died at 500 mg/m3. Decreased fetal weight was reported, but there were no differences in the incidences of skeletal malformations or anomalies between the treated and control offspring (U.S. EPA 1994).

III. ENVIRONMENTAL EFFECTS

A. Toxicity to Aquatic Organisms

Toluene has moderate acute toxicity to aquatic organisms; several toxicity values are in the range of greater than 1 mg/L and 100 mg/L. Ninety-six-hour LC50 values for fish are: 12.6-72.0 mg/L for Pimephales promelas (fathead minnow), 13-24 mg/L for Lepomis macrochirus , 28.2-59.3 mg/L for Poecilia reticulata (guppy), 240 mg/L for Ictalurus punctatus (channel catfish), and 22.8-57.68 g/L for Carassius auratus (goldfish) AQUIRE 1994). Ninety-six-hour LC50 values for crustaceans are: 9.5 ppm for Palaemonetes pugio (grass shrimp), 28 ppm for Cancer magister (crab larvae stage 1), 4.3 ppm for Crangon franciscorum (shrimp), and 9.5 mg/L for Palaemonetes pugio (daggerblade grass shrimp) (AQUIRE 1994).The EC50 values for various parameters in algae are: 245 mg/L, growth,

24 hours for Chlorella vulgaris (green algae); 20 mg/L, photosynthesis effect, 8 hours for Skeletonema costatum (diatom); and 12.5 mg/L, growth, 72 hours for Selenasrum capricornutum (green algae) (AQUIRE 1994).

B. information was found in the secondary sources searched for terrestrial organism toxicity. The oral LD50 in the rat, 5.3-5.9 g/kg), suggests that the chemical would not be acutely toxic to terrestrial animals unless present in very high concentrations. Sudies in laboratory animals also suggest that toluene would not cause developmental/reproductive effects in terrestrial species at expected environmental levels (see section IV.F). **Toxicity to Terrestrial Organisms**

No

C. Abiotic Effects

No information on abiotic effects of toluene was located in the secondary references. According to the definition provided in the Federal Register (1992), toluene is a volatile organic compound (VOC) substance. As a VOC, toluene can contribute to the formation of photochemical smog in the presence of other VOCs.

IV. Regulations to protect human health:

The Occupational Safety and Health Administration (OSHA) has set a limit of 200 parts per million (ppm) toluene for air in the workplace averaged over an eight-hour workday, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) and the National Institute for Occupational Safety and Health (NIOSH), recommend that toluene in workplace air should not exceed 100 ppm during an eight-hour work day period. The EPA has set a limit of one part per million toluene in drinking water.

V. Safety and Handling

The Manufacturing Chemists` Association Inc. (MCA) has published the Chemical; Safety Data Sheet SD 63 which describes in detail procedures for safe handling of use of toluene (46). The interstate Commerce Commission classifies toluene as a flammable liquid. Accordingly, it must be packaged in authorized containers, and shipping must comply with ICC regulations.

Properties related to safe handling are

explosive limits	1.27-7.0 vol % in air
flash point	4.4^{o}C, closed cup