

Directive on Toxic and Dangerous Wastes (542)

Any installation, establishment, or undertaking which produces, holds and/or disposes of certain toxic and dangerous wastes including phenols and phenol compounds; organic-halogen compounds, excluding inert polymeric materials and other substances referred to in this list or covered by other Directives concerning the disposal of toxic and dangerous waste; chlorinated solvents; organic solvents; biocides and phyto-pharmaceutical substances; ethers and aromatic polycyclic compounds (with carcinogenic effects) shall keep a record of the quantity, nature, physical and chemical characteristics and origin of such waste, and of the methods and sites used for disposing of such waste.

Directive on the Classification, Packaging and Labeling of Dangerous Substances (787)

Toluene is classified as a flammable, harmful substance and is subject to packaging and labeling regulations.

## 19.1 MAJOR USES

Toluene is an important raw material for organic syntheses. It is used in the production of benzene, benzyl chloride, benzoic acid, phenol, cresols, vinyl toluene, TNT and toluene diisocyanate. It is also used as a solvent for paints, rubber and resins and as a component of motor and aviation fuels (206). Toluene may be encountered as a relatively pure substance or it may be contaminated with as much as 25% benzene (206).

## 19.2 ENVIRONMENTAL FATE AND EXPOSURE PATHWAYS

### 19.2.1 Transport in Soil/Ground-water Systems

#### 19.2.1.1 Overview

Toluene may move through the soil/ground-water system when present at low concentrations (dissolved in water and sorbed on soil) or as a separate organic phase (resulting from a spill of significant quantities of the chemical). In general, transport pathways of low soil concentrations can be assessed by estimating equilibrium partitioning, as shown in Table 19-1. These calculations predict the partitioning of toluene among soil particles, soil water and soil air. The toluene associated with the water and air phases of the soil is more mobile than the adsorbed compound.

The estimates for the unsaturated topsoil model indicate that nearly all of the toluene (97%) is sorbed to the soil. A much smaller amount (2%) will be present in the soil-water phase and can thus migrate by bulk transport (e.g., the downward movement of infiltrating water), dispersion and diffusion. For the portion of toluene in the gaseous phase of the soil (1.6%), diffusion through the soil-air pores up to the ground surface, and subsequent removal by wind, will be a significant loss pathway. There is no significant difference in the partitioning calculated for 25°C and 10°C.

In saturated, deep soils (containing no soil air and negligible soil organic carbon), a much higher fraction of the toluene (48%) is likely to be present in the soil-water phase (Table 19-1) and transported with flowing ground water.

Wilson *et al.* (82) investigated the transport and fate of toluene in solutions applied to sandy soils. In a soil column receiving solutions with less than 1 mg/L toluene, approximately 40-70% was volatilized and 2-13% percolated through the soil column with minimal retardation. Between 20-60% was either degraded or not accounted for

TABLE 19-1 (F)

EQUILIBRIUM PARTITIONING CALCULATIONS FOR TOLUENE  
IN MODEL ENVIRONMENTS<sup>a</sup>

| Soil Environment                   | Estimated Percent of Total Mass of Chemical in Each Compartment |            |          |
|------------------------------------|---|------------|----------|
|                                    | Soil  | Soil-Water | Soil-Air |
| Unsaturated topsoil <sup>b,c</sup> |   |            |          |
| at 25°C                            | 96.5  | 1.9        | 1.6      |
| at 10°C                            | 97.0  | 2.0        | 0.96     |
| Saturated deep soil <sup>d</sup>   | 52.1  | 47.9       | -        |

- a) Calculations based on Mackay's equilibrium partitioning model (34,35,36); see Introduction for description of model and environmental conditions chosen to represent an unsaturated topsoil and saturated deep soil. Calculated percentages should be considered as rough estimates and used only for general guidance.
- b) Utilized estimated soil sorption coefficient:  $K_{oc} = 259$  (Estimated by Arthur D. Little, Inc.)
- c) Henry's law constant taken as 0.00661 atm·m<sup>3</sup>/mol at 25°C (74), and 0.00385 atm·m<sup>3</sup>/mol at 10°C [latter calculated using 25°C/10°C ratio of H values from Brown and Wasik (521)].
- d) Used sorption coefficient ( $K_p$ ) calculated as a function of  $K_{oc}$  assuming 0.1% organic carbon:  $K_p = 0.001 \times K_{oc}$ .

in the study. They found toluene's retardation factor in the soil columns (i.e., interstitial water velocity/velocity of toluene) to be <2.

Demirjian *et al.* (522) found that land treatment of sewage sludge containing toluene (applied at 0.0092 kg toluene/ha) led to undetectable levels of the chemical in the soil at the end of the study. (Volatilization was presumably an important pathway.) In a field study on the removal of organics from water by dune-infiltration (using water from the Rhine River), Piet *et al.* (226) actually found increases in the toluene concentration in the water after infiltration. While the

reason for the increase is not known, and may have been due to some artifact of the study, the results do indicate that toluene is easily transported by infiltrating water.

#### 19.2.1.2 Sorption on Soils

The mobility of toluene in the soil/ground-water system (and its eventual migration into aquifers) is strongly affected by the extent of its sorption on soil particles. In general, sorption on soils is expected to:

- increase with increasing soil organic matter content;
- increase slightly with decreasing temperature;
- increase moderately with increasing salinity of the soil water; and
- decrease moderately with increasing dissolved organic matter content of the soil water.

Based upon its octanol-water partition coefficient of 537, the soil sorption coefficient ( $K_{oc}$ ) is estimated to be 259. This number is indicative of moderate sorption to soils.

Nathwani et al. (523) found that toluene sorption on soils followed a Freundlich isotherm in the concentration range 1-100 mg/L. The typical Freundlich equations for toluene sorption on various soils were:

- (1)  $S = KC^n = 3.52C^{1.008}$   
Wendover silty clay (pH 5.4, 16.2% organic matter)
- (2)  $S = 2.69C^{1.002}$   
Vandreil sandy loam (pH 5.1, 10% organic matter)
- (3)  $S = 0.9C^{0.996}$   
Grimsby silt loam (pH 4.4, 1% organic matter)

where  $S$  =  $\mu\text{g}$  toluene sorbed/g soil and  
 $C$  = equilibrium solution concentration (mg/L).

#### 19.2.1.3 Volatilization from Soils

Transport of toluene vapors through the air-filled pores of unsaturated soils is an important transport mechanism for near-surface soils. In general, important soil and environmental properties influencing the rate of volatilization include soil porosity, temperature, convection currents and barometric pressure changes; important physico-chemical properties include the Henry's law constant, the vapor-soil

sorption coefficient, and, to a lesser extent, the vapor phase diffusion coefficient (31). The studies of Wilson et al. (82) and Demiryian et al. (522) provide fairly strong evidence that volatilization is an important loss mechanism for near surface soils. Sorption of toluene vapors on the soil may slow the vapor phase transport; Politzki et al. (516) have shown, for example, that the vapor pressure of toluene in the presence of (and thus partially sorbed to) silica gel was decreased by a factor of almost  $10^4$  from the pure compound value.

The Henry's law constant (H), which provides an indication of a chemical's tendency to volatilize from solution, increases significantly with increasing temperature (28). Moderate increases in H are also expected with increasing salinity due to a decrease in toluene's solubility (517).

#### 19.2.2 Transformation Processes in Soil/Ground-water Systems

The persistence of toluene in soil/ground-water systems is not well documented. In most cases, it should be assumed that the chemical will persist for months to years (or more). Toluene that has been released into the air will eventually undergo photochemical oxidation; a tropospheric lifetime of 15 hours has been estimated (10).

Toluene under normal environmental conditions is not expected to undergo hydrolysis (10,33). Further, toluene is not expected to be susceptible to oxidation or reduction reactions in the soil/ground-water environment.

Available data indicate that toluene is biodegradable in the soil/ground-water environment (10,524,525,236,55,519). A number of species of microorganisms are capable of using toluene as the sole carbon source. Toluene is easily degraded in adaptable mixed cultures (55). However, in most soil/ground-water systems such aerobic degradation would be of minimal importance because of the low concentration of microorganisms (at depth) and the low dissolved oxygen (anaerobic) conditions. No data are available on the susceptibility of toluene to anaerobic biodegradation.

#### 19.2.3 Primary Routes of Exposure From Soil/Ground-water Systems

The properties of toluene and the above discussion of fate pathways suggest that toluene is highly volatile from aqueous solutions, moderately adsorbed by soil and has a low potential for bioaccumulation. This compound may volatilize from soil surfaces; however, the portion not removed by volatilization may eventually migrate to ground water. These fate characteristics suggest several potential exposure pathways.

Volatilization of toluene from a disposal site, particularly during drilling or restoration activities, could result in inhalation exposures. The potential for ground water contamination is high, particularly in sandy soil. Mitre (83) reported that toluene has been found at 95 of the 546 National Priority List (NPL) sites. It was detected at 74 sites in ground water, 41 sites in surface water and 12 sites in air.

This compound was also reported in the USEPA (531) Groundwater Supply Survey (GWSS). This survey examined 945 finished water supplies that use ground-water sources. The results for toluene are summarized below:

| Sample Type                                   | Occurrences* |     | Median of Positives (µg/L) | Maximum (µg/L) |
|---|--------------|-----|----------------------------|----------------|
|   | No.          | %   |                            |                |
| Random  |              |     |                            |                |
| Supplies serving <10,000 people (280 samples) | 4            | 1.4 | 0.62                       | 0.85           |
| Supplies serving >10,000 people (186 samples) | 2            | 1.1 | 2.6                        | 2.9            |
| Non-Random                                    |              |     |                            |                |
| Supplies serving <10,000 people (321 samples) | 4            | 1.2 | 0.67                       | 0.79           |
| Supplies serving >10,000 people (158 samples) | 1            | 0.6 | 1.5                        | 1.5            |

\*Samples having levels over quantification limit of 0.5 µg/L.

The random results are intended to statistically represent the U.S. ground-water drinking water supplies. The non-random samples were chosen by the states as being potentially contaminated. Toluene was also detected in the National Organic Monitoring Survey (NOMS) (90).

The properties of toluene and the results described above indicate that this compound has the potential for movement in soil/ground-water systems. This compound may eventually reach surface waters by this mechanism, suggesting several other exposure pathways:

- Surface waters may be used as drinking water supplies, resulting in direct ingestion exposure;
- Aquatic organisms residing in these waters may be consumed, also resulting in ingestion exposures through bioaccumulation;
- Recreational use of these waters may result in dermal exposures;
- Domestic animals may consume or be dermally exposed to contaminated ground or surface waters; the consumption of meats and poultry could then result in ingestion exposures.

In general, exposures associated with surface water contamination can be expected to be lower than exposure from drinking contaminated ground water for two reasons. First, the Henry's law constant for toluene suggests that it will volatilize upon reaching surface waters. Secondly, the bioconcentration factor for this compound is low, suggesting limited bioaccumulation in aquatic organisms or domestic animals.

#### 19.2.4 Other Sources of Exposure

Toluene is a widely used chemical, predominantly in gasoline, chemical synthesis (benzene, phenol and others), and as a solvent. As a result of emissions during production, use, and disposal, and because of high volatility, toluene has become pervasive in the environment.

The data presented above on the Groundwater Supply Survey (531) suggest that toluene is found in a limited number of ground-water supplies used as drinking water. Coniglio *et al.* (223) in a summary of data from SRI, NOMS and NORS, found that toluene was detected at a frequency of 19.4% in finished surface water.

The volatility of toluene suggests that it may be found in air. Brodzinsky and Singh (84) compiled all available atmospheric monitoring data for a number of volatile organics. For toluene, they had data for 3498 locations. In rural and remote areas, the median concentration was 2.5  $\mu\text{g}/\text{m}^3$ . In urban and suburban areas, the median concentration was 41  $\mu\text{g}/\text{m}^3$ . In source-dominated locations, the median concentration was 17  $\mu\text{g}/\text{m}^3$ . These results indicate that individuals are exposed via inhalation even in rural and remote areas.

Toluene has also been identified in cigarette smoke. According to the NRC (743), the average toluene exposure is 0.1 mg per cigarette. This route would likely represent the greatest source of exposure for smokers.

### 19.3 HUMAN HEALTH CONSIDERATIONS

#### 19.3.1 Animal Studies

##### 19.3.1.1 Carcinogenicity

Carcinogenicity data for toluene are extremely limited and are insufficient for evaluating its carcinogenic potential. Toluene applied to the skin of mice for 1 year failed to elicit skin neoplasms or an increased frequency of systemic tumors. However, it was not clear whether the toluene was allowed to evaporate or was applied under an occlusive dressing (619). In contrast, skin cancers were observed

in 2 mice out of a group of 30 who were subjected to topical application of 16 to 20  $\mu$ l of toluene twice weekly for 72 weeks (43). Toluene is being tested for carcinogenic activity by the National Toxicology Program (594) by inhalation in rats (0, 600, 1200 ppm) and mice (0, 120, 600, 1200 ppm); histopathological analysis is now in progress.

#### 19.3.1.2 Mutagenicity

Cytogenetic data in lymphocytes of toluene-exposed workers are contradictory. Bauchinger et al. (622) observed a statistically significant number of chromatid breaks, exchanges and gaps among workers employed for 16 years in a rotogravure plant. Vapor concentrations ranged from 200-300 ppm. Other investigators reported negative results in chromosomal analysis of workers exposed to vapor concentrations in the 7-200 ppm range (623,724).

Toluene did not induce recessive lethals in Drosophila melanogaster exposed to 500 or 1000 ppm by feeding for 24 hours nor did it induce chromosomal aberration in male Wistar rats exposed to 300 ppm by inhalation, 6 hr/day, 5 days/week for 15 weeks (624).

#### 19.3.1.3 Teratogenicity, Embryotoxicity and Reproductive Effects

Toluene was reported to be teratogenic in CD-1 mice after oral administration of 1.0 mL/kg per day on days 6 through 15 of gestation, producing a statistically significant increase in the incidence of cleft palate. Increased embryonic lethality occurred at 0.3, 0.5 and 1.0 mL/kg with decreased fetal weight noted at the 2 upper dosage levels (620).

Other investigators have not found toluene to be teratogenic. No teratogenic effects were observed in rats exposed by inhalation to 400 ppm continuously on days 1 through 8 or in rats exposed to 375 ppm 8 hours daily, on days 1 through 21. Some fetal growth retardation and maternal mortality occurred at the higher exposure level. Similar growth retardation was seen in mice exposed continuously to 400 ppm of toluene vapor on days 6 through 13 of gestation (53).

#### 19.3.1.4 Other Toxicologic Effects

##### 19.3.1.4.1 Short-term Toxicity

Animal experiments indicate that the main toxic effects of acute inhalation exposure are upon the central nervous system. In general, 4 to 8-hour vapor exposures of up to 1000 ppm produce little or no effect in various animal species; at concentrations ranging from 1000 to 2000 ppm, effects include instability, incoordination, light narcosis and



tremors (206). The minimum lethal vapor concentration for mice was found to be 5300 ppm in an 8-hour exposure (206). An  $LC_{50}$  value of 5320 ppm·8hr was recorded for mice (47). Toluene has not been shown to have any effects on the blood or blood-forming organs after repeated exposures to vapor concentrations ranging from 90 to 2000 ppm. Hepatotoxicity has been reported to be slight or non-existent in various studies (206,70).

A recent study has found that toluene induces hearing loss in rats after short-term, high-level inhalation exposures. Three-day exposures to 1500 ppm for 14 hours daily or 2000 ppm for 8 hours daily induced hearing loss; single exposures to 4000 ppm for 4 hours or 2000 ppm for 8 hours were without effect. Exposure to vapor concentrations of 400-700 ppm were without effect even after 16 weeks of exposure (621).

When instilled into rabbit eyes, toluene causes transient conjunctival irritation; no reports of corneal damage in animals have been found (19,206).

Dermal  $LD_{50}$  values of 12.1 and 14 g/kg were determined for the rabbit (12,47). An oral  $LD_{50}$  of 5 g/kg was recorded for rats (47).

#### 19.3.1.4.2 Chronic Toxicity

Long-term ingestion or inhalation of toluene resulted in no adverse effects in various animal species. Rats given oral doses of 118 to 590 mg/kg/day for 193 days exhibited no effects (210). In general, inhalation exposures of rats, guinea pigs, dogs and primates at concentrations ranging from 107 to 1515 ppm, 6-8 hours daily for 90-127 days produced no adverse effects (12).

### 19.3.2 Human and Epidemiologic Studies

#### 19.3.2.1 Short-term Toxicologic Effects

No reports involving human ingestion of toluene were found. The primary hazard associated with acute inhalation exposure to high levels of toluene is CNS depression (207). Controlled exposure of human subjects to 200 ppm ( $750 \text{ mg/m}^3$ ) for 8 hours produced mild fatigue, weakness, confusion, lacrimation and tingling of the skin. At 600 ppm, additional effects including euphoria, headache, dizziness, dilated pupils and nausea became evident. After 8 hours at 800 ppm, symptoms were more pronounced; after-effects included nervousness, muscular fatigue and insomnia persisting for several days (46).

Toluene is frequently used as a solvent of abuse due to the euphoria and inebriation-like symptoms associated with inhalation of

its vapors either from paint or glue or in its pure form. Exposure levels in these cases have been estimated to be as high as 5000 ppm (12). Long-term abuse of toluene (3 to 15 years) has resulted in emotional and intellectual disturbances as well as central nervous system impairment (70). Symptoms include tremors, weakness, diminished reflexes and sensory loss (204). Other complaints involve gastrointestinal disorders (17). Several deaths due to toluene abuse have been reported. Although most have been attributed to cardiac arrhythmias or asphyxiation, a recent case report of toluene abuse attributed death to severe fluid volume depletion and electrolyte abnormalities (decreased serum potassium, calcium and phosphorus) (205). These effects result from long-term, high-level inhalation exposures.

Impairment of reaction time was observed in humans after 20 minutes exposure to 300 ppm (1125 mg/m<sup>3</sup>) and after 7 hours exposure to 200 ppm (750 mg/m<sup>3</sup>) (70,206).

Grant (19) reports that eye irritation is noticeable at vapor levels of 300 to 400 ppm. Toluene splashed in the eyes of workers resulted in transient corneal damage and conjunctival irritation from which they recovered within 48 hours (19).

Prolonged or repeated skin contact may cause drying and dermatitis. For liquid toluene, the rate of percutaneous absorption ranges from 14 to 23 mg/cm<sup>2</sup> per hour (206). Dermal absorption of the vapor is negligible (70).

A higher incidence of menstrual disorders has been reported in women occupationally exposed to toluene as well as other solvents. Children born to these women were said to experience more frequent fetal asphyxia and to be more often underweight. There are no accounts of a teratogenic effect in humans being linked to toluene exposure (207).

### 19.3.2 Chronic Toxicologic Effects

The industrial experience with toluene has generally been good. In occupational exposure, vapor concentrations ranging from 80 to 160 ppm produced no changes in the blood or liver of workers exposed for "several years." One worker exposed to mean vapor levels of 250 ppm experienced conjunctival irritation, insomnia, and nervousness (625).

A 1942 study noted enlarged livers and blood disorders in 21% of painters exposed to toluene concentrations ranging from 100-1100 ppm. However, these results are considered suspect since toluene manufactured at this time may have been contaminated with as much as 15% benzene (626). Other early studies also implicated toluene as the

cause of various blood disorders. The current view is that these effects were entirely attributable to benzene contamination (206).

#### 19.3.3.3 Levels of Concern

The USEPA (355) has established an ambient water quality criterion for the protection of human health for toluene of 14.3 mg/L. This criterion was developed based on the no-observed-effect level of 590 mg/kg/day for rats ingesting toluene for 193 days (210), an uncertainty factor of 1000, 100% absorption, a bioconcentration factor of 10.7 for fish and the assumption the two liters of drinking water and 6.5 g of contaminated fish are consumed by a 70-kg adult per day.

The acceptable daily intake for toluene calculated by the USEPA was 30 mg/day (670).

OSHA (298) currently permits exposure to 200 ppm (750 mg/m<sup>3</sup>) averaged over an 8-hour work-shift, with a ceiling level of 300 ppm and a maximum acceptable peak of 500 ppm for 10 minutes. The ACGIH (3) recommends a threshold limit value of 100 ppm (375 mg/m<sup>3</sup>), with a short-term exposure limit of 150 ppm.

#### 19.3.3.4 Hazard Assessment

Toluene is a central nervous system depressant with a low toxicity. CNS effects are noted with high (>1000 ppm), acute inhalation exposures in experimental animals (206). A recent report (621) has also linked hearing loss in rats to high-level, toluene exposures (e.g., 1500 ppm, 14 hr/day for 3 days). No adverse effects have been reported for long-term, low-level (<100 ppm) exposures in laboratory animals (12,621). Ingestion of 590 mg/kg/day for 7 months was without effect in rats (210); no human ingestion data were found.

Toluene has been inadequately tested to permit assessment of its carcinogenic potential. Cytogenetic data in lymphocytes of toluene-exposed workers are contradictory (623,724). Negative mutagenic effects have been reported for a rat chromosomal study and a test in Drosophila (624). One study noted an increased incidence of cleft palate in mice, given 1 mL/kg toluene by gavage during gestation (620). No teratogenic effects were observed in either rats or mice exposed to 375-400 ppm by inhalation (53).

The USEPA has estimated an acceptable daily intake of 30 mg of toluene per day for a 70-kg individual based on a no-effect-level in rats ingesting toluene for 7 months (670).

19.4 SAMPLING AND ANALYSIS CONSIDERATIONS

Determination of toluene concentrations in soil and water requires collection of a representative field sample and laboratory analysis. Due to the volatility of toluene, care is required to prevent losses during sample collection and storage. Soil and water samples should be collected in airtight containers with no headspace; analysis should be completed within 14 days of sampling. In addition to the targeted samples, quality control samples such as field blanks, duplicates, and spiked matrices may be specified in the recommended methods.

EPA-approved procedures for the analysis of toluene, one of the EPA priority pollutants, in aqueous samples include EPA Methods 602, 624, and 1624 (65). An inert gas is bubbled through the aqueous sample in a purging chamber at ambient temperature, transferring the toluene from the aqueous phase to the vapor phase and onto a sorbent trap. The trap is then heated and backflushed to desorb the toluene and transfer it onto a gas chromatographic (GC) column. The GC column is programmed to separate the volatile organics; toluene is then detected with a photo-ionization detector (Method 602) or a mass spectrometer (Methods 624 and 1624).

The EPA procedures recommended for toluene analysis in soil and waste samples, Methods 8020 and 8240 (63), differ from the aqueous procedures primarily in the method by which the analyte is introduced into the GC. The recommended method involves dispersing the soil or waste sample in methanol or polyethylene glycol to dissolve the toluene. A portion of the solution is then combined with water and purged as described above. Other sample introduction techniques include direct injection and a headspace method.

Typical toluene detection limits that can be obtained in wastewaters and non-aqueous samples (wastes, soils, etc.) are shown below. The actual detection limit achieved in a given analysis will vary with instrument sensitivity and matrix effects.

| <u>Aqueous Detection Limit</u> | <u>Non-Aqueous Detection Limit</u> |
|--------------------------------|------------------------------------|
| 0.2 µg/L (Method 602)          | 1 µg/g (Method 8020)               |
| 6.0 µg/L (Method 624)          | 1 µg/g (Method 8240)               |
| 10 µg/L (Method 1624)          |                                    |

## XYLENE

### Introduction:

Xylenes are petrochemical derivatives used as solvents and as components of detergents and other industrial and household products.<sup>1</sup> Xylene is formed in petroleum, coal tar, and coal gas distillation, and is insoluble in water. It is used in aviation gasolines, in rubber cements, in the manufacture of solvents and protective coatings, and in the synthesis of organic chemicals. U.S. production of xylenes in 1973 was over 5.94 billion pounds.<sup>2</sup> Commercial products are usually mixtures of the dimethylbenzene isomers, ortho-, meta-, and para-xylenes.<sup>3</sup> The meta-isomer predominates in commercial products. Xylenes were rated 13th out of 7,000 chemicals surveyed for occupational exposure with more than 4 million workers believed to be exposed. The USEPA estimates that nearly 410 million kg of xylenes are released into the environment each year.<sup>1</sup> Xylenes have been found in drinking water in New Orleans at 0.29 mg/l and coastal waters of the Gulf of Mexico (ortho=0.3-10.1 ng/l; meta=2.7 ng/l; and para=24.4 ng/l).<sup>3</sup> Traces of xylene have been detected in one community well in Wisconsin.<sup>4</sup>

### Human Exposure Routes:

Xylenes have been detected in both air and water but no residues have been found in food. Much of the postulated human exposure comes from the air.

### Acute Toxicity:

The following values have been reported in the literature:

- \*Inhalation LC<sub>50</sub> (adult female rats): 4,700 ppm (p-xylene)
- \*Intraperitoneal LD<sub>50</sub> (female rats): 3.8 mg/kg (p-xylene)
- \*Oral LD<sub>50</sub> (rats): 4.3 mg/kg
- \*Oral LD<sub>50</sub> (rats): 4,300-5,000 mg/kg b.w.
- \*Inhalation (4 hour) LC<sub>50</sub>: 20,000-29,000 mg/m<sup>3</sup>

Animal experiments suggest that xylenes are relatively non-toxic when ingested or inhaled for short periods of time.

### Chronic Toxicity:

Inhalation studies using rats and dogs exposed to 770, 2,000, and 3,500 mg/m<sup>3</sup> for 6 hours/day, 5 days/week for 13 weeks showed no differences from control animals. Numerous tests done with laboratory animals suggest limited adverse effects from long-term exposure to xylenes.

### Human Health Effects:

Human exposure to xylenes produces central nervous system disturbances as shown by changes in numerative ability, reaction time, short-term memory and electroencephalographic patterns. The lowest oral lethal dose for humans has been reported at 50 mg/kg. In an experiment in which human volunteers were exposed to 1,300 mg/m<sup>3</sup> xylene in inspired air, researchers found reduction in 3 out of 4 mental performance tests. Adverse psycho-physiological effects

were seen in human volunteers exposed to m-xylene at 90-200 ppm for 5 consecutive days. In addition to central nervous system effects, data indicates that xylenes also affect the liver.

Mutagenicity:

Xylene was not mutagenic in an Ames assay with or without activation nor by other short-term in vitro mutagenicity bioassays.

Carcinogenicity:

No data is yet available from the NCI Carcinogenesis Bioassay Program.

Teratogenicity/Reproductive Effects:

Twenty CFY rats exposed to 1,000 mg/m<sup>3</sup> of mixed xylenes during days 9-14 of pregnancy developed fused sternbrae and extra ribs, which were interpreted as signs of embryotoxicity rather than teratogenicity. In another test using Charles River rats exposed to xylenes up to 400 ppm, no teratogenic effects were reported.<sup>3</sup> Xylene has been reported to produce developmental abnormalities in chicken embryos.<sup>2</sup> Xylenes have been reported to cross the human placenta.<sup>1</sup>

Environmental Fate:

Although the partition coefficient calculated for xylenes predicts environmental accumulation, the rapid oxidation of xylenes to their corresponding polar metabolites seems to preclude bioaccumulation in higher animals.<sup>1</sup>

Risk Assessment:

Xylene did not appear to be mutagenic by the Ames test with or without activation, or to be teratogenic in pregnant rats. There is no evidence reported on carcinogenicity of xylene.

Based on a toxicological study by Jenkins et al (1970)<sup>5</sup>, and converting inhalation dosage into mg/kg/day, the EPA has determined:

NOEL: 62 mg/kg/day  
Safety Factor: 1,000

Recommendations and Conclusions:

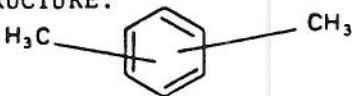
Utilizing the federally-provided numbers above and the procedures outlined in ss 160.07(4) and 160.13, the calculations for the Department of Health and Social Services recommended groundwater standard are as follows:

$$\frac{62 \text{ mg/kg/day} \times 10 \text{ kg} \times 100\%}{1,000 \times 1 \text{ liter}} = .62 \text{ mg/liter}$$
$$= 620 \text{ } \mu\text{g/liter}$$

Recommended Enforcement Standard: 620  $\mu$ g/liter (620 ppb)  
Recommended Preventive Action Limit factor: 20%

References:

1. National Research Council, 1980. Drinking Water and Health. National Academy Press. Washington, D.C. Vol. 3, p. 178-181
2. National Research Council, 1977. Drinking Water and Health. National Academy Press. Washington, D.C. Vol. 1, p. 778-789
3. USEPA, 1981. Advisory Opinion for Xylenes. Office of Drinking Water. Washington, D.C. p. 1-9
4. DNR News Release, November 1, 1984
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|  |               |  |  |  |  |
|--|---------------|--|--|--|--|
| COMMON SYNONYMS:<br>Dimethylbenzene<br>Xylol |               | STRUCTURE:<br> |  | AIR W/V CONVERSION<br>FACTORS at 25°C (12)<br><br>4.34 mg/m <sup>3</sup> ≅ 1 ppm<br>0.2304 ppm ≅ 1 mg/m <sup>3</sup> |  |
| ISOMER                                       | CAS REG. NO.: | NIOSH NO.:   | FORMULA:<br>C <sub>8</sub> H <sub>10</sub> | MOLECULAR WEIGHT:<br>106.17  |  |
| mixed  | 1330-20-7     | ZE2100000  |  |  |  |
| m  | 108-38-3      | ZE2275000  |  |  |  |
| o  | 95-47-6       | ZE2450000  |  |  |  |
| p  | 106-42-3      | ZE2625000  |  |  |  |

|            |  |
|------------|--|
| REACTIVITY | Xylenes may generate heat, react vigorously, and possibly ignite or explode in contact with oxidizing mineral acids or other strong oxidizing agents (512,507,38,511). |
|------------|--|

|                       |   |
|-----------------------|---|
| PHYSICO-CHEMICAL DATA | ● Physical State (at 20°C): liquid (23)   |
|                       | ● Color: colorless (23)   |
|                       | ● Odor: aromatic (2)  |
|                       | ● Odor Threshold: 1.1 ppm (384)   |
|                       | ● Liquid Density (g/ml at 25°C): 0.8802(o-); 0.8642(m-); 0.8610(p-) (21)  |
|                       | ● Freezing/Melting Point (°C): -25.2(o-); -47.9(m-); +13.3(p-) (21)   |
|                       | ● Boiling Point (°C): 144.4(o-); 139.1(m-); 138.7(p-) (21)  |
|                       | ● Flash Point (°C): 31(o-); 29(m-); 27(p-) (21)   |
|                       | ● Flammable Limits in Air, % by Volume: 1.0-7.0(o-,m-,p-) (504,12)  |
|                       | ● Autoignition Temperature (°C): 464(o-); 528-530(m-); 529(p-) (51,506, 60,513)   |
|                       | ● Vapor Pressure (mm Hg at 20°C): 7(o-); 9(m-); 9(p-) (38)  |
|                       | ● Saturated Concentration in Air (mg/m <sup>3</sup> at 20°C): 40,750(o-); 52,400(m-,p-) (ADL estim)   |
|                       | ● Solubility in Water (mg/L at 20°C): 0.3(o-,m-,p-) (38)  |
|                       | ● Viscosity (cp at 20°C): 0.802(o-); 0.0608(m-); 0.635(p-) (48)   |
|                       | ● Surface Tension (dyne/cm at 20°C): 32.5(o-); 31.2(m-); 28.3(p-) (21)  |
|                       | ● Log (Octanol-Water Partition Coefficient), log K <sub>ow</sub> : 3.12(o-); 3.20(m-); 3.15(p-); 3.16(avg) (29)                                   |
|                       | ● Soil Adsorption Coefficient, K <sub>oc</sub> : 691 (652)  |
|                       | ● Henry's Law Constant (atm·m <sup>3</sup> /mol at 25°C): 4.94x10 <sup>-3</sup> (o-); 6.91x10 <sup>-3</sup> (m-); 7.01x10 <sup>-3</sup> (p-) (74) |
|                       | ● Bioconcentration Factor: 70 (avg estim) (659)   |

NOTE: Throughout this chapter, the term xylene refers to the mixed isomers unless otherwise specified. Where appropriate, the isomers are identified by the prefixes o-(ortho), m-(meta) or p-(para).



|   |  |
|---|--|
| PERSISTENCE<br>IN THE SOIL-<br>WATER SYSTEM | Relatively mobile in soil-water systems, especially in aqueous phase. Volatilization through air-filled pores is also possible. Chemical is resistant to hydrolysis but is probably biodegradable. Should assume chemical could persist for months to years (or longer). |
|---|--|

|                            |  |
|----------------------------|--|
| PATHWAYS<br>OF<br>EXPOSURE | The primary pathway of concern from soil-water systems is the migration of xylene to ground-water drinking water supplies. Data from NPL sites indicate that migration of this compound has occurred in the past. Inhalation resulting from volatilization from surface soils may also be important. |
|----------------------------|--|

|  |   |                          |                        |                      |                       |                 |           |
|--|---|--------------------------|------------------------|----------------------|-----------------------|-----------------|-----------|
| HEALTH<br>HAZARD<br>DATA   | <p><u>Signs and Symptoms of Short-term Human Exposure (54):</u><br/>                 Acute exposure to high concentrations of xylene vapors in air may cause CNS depression with symptoms including dizziness, drowsiness, nausea, vomiting, abdominal pain, loss of appetite, pulmonary edema, and unconsciousness, as well as reversible effects on the liver and kidneys. Liquid xylene and high vapor concentrations are irritating to the eyes and the vapor may cause transient, reversible damage to the cornea. Aspiration of liquid into the lungs may cause chemical pneumonitis, pulmonary edema and hemorrhage.</p> |                          |                        |                      |                       |                 |           |
|  | <p><u>Toxicity Based on Animal Studies:</u></p> <table border="0"> <tr> <td>LD<sub>50</sub> (mg/kg)</td> <td>LC<sub>50</sub> (ppm)</td> </tr> <tr> <td>oral [rat] 4300 (47)</td> <td>inhalation [rat] (47)</td> </tr> <tr> <td>skin -- no data</td> <td>5000-4 hr</td> </tr> </table>   | LD <sub>50</sub> (mg/kg) | LC <sub>50</sub> (ppm) | oral [rat] 4300 (47) | inhalation [rat] (47) | skin -- no data | 5000-4 hr |
|  | LD <sub>50</sub> (mg/kg)  | LC <sub>50</sub> (ppm)   |                        |                      |                       |                 |           |
|  | oral [rat] 4300 (47)  | inhalation [rat] (47)    |                        |                      |                       |                 |           |
|  | skin -- no data   | 5000-4 hr                |                        |                      |                       |                 |           |
|  | <p><u>Long-Term Effects:</u> Possible damage to liver and kidneys, but such effects have not been demonstrated with certainty</p>   |                          |                        |                      |                       |                 |           |
| <p><u>Pregnancy/Neonate Data:</u> Negative in rats; cleft palates in mice but only at near lethal levels</p> |   |                          |                        |                      |                       |                 |           |
| <p><u>Mutation Data:</u> Negative</p>  |   |                          |                        |                      |                       |                 |           |
| <p><u>Carcinogenicity:</u> No data</p>   |   |                          |                        |                      |                       |                 |           |

|                                    |   |
|------------------------------------|---|
| HANDLING<br>PRECAUTIONS<br>(38,52) | Handle xylene only with adequate ventilation • Vapor concentrations of 100-1000 ppm: chemical cartridge respirator with full facepiece and organic vapor cartridge • 1000-5000 ppm: any supplied-air respirator or self-contained breathing apparatus with full facepiece or gas mask with organic vapor canister • Chemical goggles if there is probability of eye contact • Natural rubber, neoprene, PVA, PVC, gloves/apron/boots and protective clothing to prevent prolonged or repeated skin contact with liquid. |
|------------------------------------|---|

|  |   |
|--|---|
| EMERGENCY<br>FIRST AID<br>TREATMENT<br>(38,54) | <p><u>Ingestion:</u> Do not induce vomiting. Get medical attention immediately • <u>Inhalation:</u> Move victim to fresh air. Give artificial respiration if necessary. Keep victim warm and at rest. Seek medical attention • <u>Skin:</u> Remove contaminated clothing. Wash skin with soap and water. If irritation persists, get medical attention • <u>Eye:</u> Irrigate with large amounts of water. Get medical attention.</p> |
|--|---|

## ENVIRONMENTAL AND OCCUPATIONAL STANDARDS AND CRITERIA

AIR EXPOSURE LIMITS:Standards

- OSHA PEL (8-hr TWA): 100 ppm
- AFOSH PEL (8-hr TWA): 100 ppm; STEL (15-min): 150 ppm

Criteria

- NIOSH IDLH (30-min): 10,000 ppm
- ACGIH TLV<sup>®</sup> (8-hr TWA): 100 ppm
- ACGIH STEL (15-min): 150 ppm

WATER EXPOSURE LIMITS:Drinking Water Standards

None established

EPA Health Advisories

In the absence of formal drinking water standards, the EPA (383) has developed the following Health Advisories (formerly termed SNARLs) for noncarcinogenic risk for short and long-term exposure to xylene in drinking water:

- 1 day: 12 mg/L
- 10 days: 1.4 mg/L
- long-term: 0.62 mg/L

EPA Ambient Water Quality Criteria (355)

- Human Health  
No criterion established; xylene is not a priority pollutant.
- Aquatic Life  
No criterion established; xylene is not a priority pollutant.

## REGULATORY STATUS (as of October 1, 1985)

Promulgated Regulations• Federal ProgramsClean Water Act (CWA)

Xylene is designated a hazardous substance under CWA. It has a reportable quantity (RQ) limit of 454 kg (347,556).

Safe Drinking Water Act (SDWA)

In states with an approved Underground Injection Control program, a permit is required for the injection of xylene-containing wastes designated as hazardous under RCRA (295).

Resource Conservation and Recovery Act (RCRA)

Xylene is identified as a toxic, ignitable hazardous waste (U239) (329).

Toxic Substances Control Act (TSCA)

Manufacturers, processors or distributors of xylene must report production, usage and disposal information to EPA. They, as well as others who possess health and safety studies on xylene, must submit them to EPA (334,335).

Comprehensive Environmental Response Compensation and Liability Act (CERCLA)

Xylene is designated a hazardous substance under CERCLA. It has a reportable quantity (RQ) limit of 454 kg. Reportable quantities have also been issued for RCRA hazardous waste streams containing xylene but these depend upon the concentration of the chemicals present in the waste stream (556).

Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)

Xylene is exempt from a tolerance requirement when used as a solvent in pesticide formulations applied to growing crops or to animals. Exemptions also apply when it is used as a solvent in pesticide formulations for grain storage. However, it must meet specifications for ultraviolet absorbance (315). In addition it is exempt when applied to irrigation conveyance systems as an emulsion at an initial concentration not to exceed 750 ppm. It is not to be applied where return flows would contain residues in excess of 10 ppm (321).

Occupational Safety and Health Act (OSHA)

Employee exposure to xylene in any 8-hour work-shift of a 40-hour work-week shall not exceed an 8-hour time-weighted-average (TWA) of 100 ppm (298).

Hazardous Materials Transportation Act (HMTA)

The Department of Transportation has designated xylene as a hazardous material which is subject to requirements for packaging, labeling and transportation (306).

10/85

Food, Drug and Cosmetic Act (FDCA)

Xylene is approved for use as an indirect food additive (362).

- State Water Programs

California has an action level of 620 µg/L for drinking water either for a single xylene isomer or for the sum of the 3 isomers (731). Iowa has an unpublished internal criterion of 82 µg/L for streams (731).

Proposed Regulations

- Federal Programs

- Resource Conservation and Recovery Act (RCRA)

EPA has proposed listing spent solvent mixtures containing 10% or more xylene as non-specific sources of hazardous wastes (780).

- State Water Programs

Wisconsin has proposed a ground-water enforcement standard of 620 µg/L for xylene (731).

EEC Directives

- Directive on Ground Water (538)

Direct discharge into ground water (i.e., without percolation through the ground or subsoil) of organohalogen compounds and substances which may form such compounds in the aquatic environment, substances which possess carcinogenic, mutagenic or teratogenic properties in or via the aquatic environment, and mineral oils and hydrocarbons is prohibited. Appropriate measures deemed necessary to prevent indirect discharge into ground water (i.e., via percolation through ground or subsoil) of these substances shall be taken by member countries.

- Directive Relating to the Classification, Packaging and Labeling of Dangerous Preparations (Solvents) (544)

Xylene is listed as a Class II/c harmful substance and is subject to packaging and labeling regulations.

- Directive on Toxic and Dangerous Wastes (542)

Any installation, establishment, or undertaking which produces, holds and/or disposes of certain toxic and dangerous wastes including phenols and phenol compounds; organic-halogen compounds, excluding inert polymeric materials and other substances referred to in this list or covered by other Directives concerning the disposal of toxic and dangerous waste; chlorinated solvents; organic solvents; biocides and phyto-pharmaceutical substances; ethers and aromatic polycyclic compounds (with carcinogenic effects) shall keep a record of the quantity, nature, physical and chemical characteristics and origin of such waste, and of the methods and sites used for disposing of such waste.

- Directive on the Classification, Packaging and Labeling of Dangerous Substances (787)

Xylene is classified as a harmful substance and is subject to packaging and labeling regulations.

## 21.1 MAJOR USES

Commercial xylene is a mixture of the ortho, meta and para isomers, with the meta form usually the principal component (~60-70%). Xylene may also contain 6 to 10% impurities such as benzene, ethyl benzene, trimethylbenzene, toluene, phenol, thiophene, pyridene and nonaromatic hydrocarbons. The xylenes are widely used as fuel components and as solvents for inks, rubbers, gums, resins, adhesives, lacquers, paints and insecticides. Xylenes are commonly used in the chemical industry as intermediates. Specifically, o-xylene is used in the manufacture of phthalic anhydride which is a basic building block for plasticizers. Meta-xylene is an intermediate in the preparation of isophthalic acid which is the base of unsaturated polyester resins. Commercially, para-xylene is the most important isomer. Almost all is converted to terephthalic acid or dimethylterephthalate and used to make fibers, films and resins (2,12,21).

## 21.2 ENVIRONMENTAL FATE AND EXPOSURE PATHWAYS

### 21.2.1 Transport in Soil/Ground-water Systems

#### 21.2.1.1 Overview

Xylene may move through the soil/ground-water system when present at low concentrations (dissolved in water and sorbed on soil) or as a separate organic phase (resulting from a spill of significant quantities of the chemical). In general, transport pathways of low soil concentrations can be assessed by using an equilibrium partitioning model as shown in Table 21-1. These calculations predict the partitioning of xylene among soil particles, soil water and soil air. The portions of xylene associated with the water and air phases of the soil are more mobile than the adsorbed portion.

The estimates for the unsaturated topsoil model indicate that nearly all of the xylene (98.8%) is expected to be sorbed to the soil. A much smaller amount (0.7%) is expected to be present in the soil-water phase and thus available to migrate by bulk transport (e.g., the downward movement of infiltrating water), dispersion and diffusion. For the portion of xylene in the gaseous phase of the soil (0.5%), diffusion through the soil-air pores up to the ground surface, and subsequent removal by wind, will be a significant loss pathway.

TABLE 21-1 (G)

EQUILIBRIUM PARTITIONING CALCULATIONS FOR XYLENE  
IN MODEL ENVIRONMENTS<sup>a</sup>

| Soil Environment                           | Estimated Percent of Total Mass of Chemical in Each Compartment |            |          |
|--|---|------------|----------|
|  | Soil  | Soil-Water | Soil-Air |
| Unsaturated topsoil <sup>b,c</sup> at 25°C | 98.8  | 0.7        | 0.5      |
| Saturated deep soil <sup>d</sup>           | 74.4  | 25.6       | -        |

- a) Calculations based on Mackay's equilibrium partitioning model (34,35,36); see Introduction for description of model and environmental conditions chosen to represent an unsaturated topsoil and saturated deep soil. Calculated percentages should be considered as rough estimates and used only for general guidance.
- b) Utilized estimated soil sorption coefficient:  $K_{oc} = 691$  (Estimated by Arthur D. Little, Inc.)
- c) Henry's law constant taken as  $0.007 \text{ atm}\cdot\text{m}^3/\text{mol}$  at 25°C.
- d) Used sorption coefficient ( $K_p$ ) calculated as a function of  $K_{oc}$  assuming 0.1% organic carbon:  $K_p = 0.001 \times K_{oc}$ .

In saturated, deep soils (containing no soil air and negligible soil organic carbon), a much higher fraction of the xylene (26%) is likely to be present in the soil-water phase (Table 21-1) and transported with flowing ground water.

Laboratory batch and column experiments by Schwarzenbach and Westall (228) showed that p-xylene could be fairly mobile in soil/ground-water systems. The relative velocity (velocity of xylene/velocity of water) was 0.05 in a river sediment and 0.45 in aquifer material. Demirjian *et al.* (522) found that xylene applied (at 0.13  $\mu\text{g}/\text{ha}$ ) in a sludge land-treatment study was not detectable in the soil at the end of the study period. Volatilization losses may have been an important transport pathway.

In a field study on the removal of organics in water by dune-infiltration (using water from the Rhine River), Piet *et al.* (226) actually found increases in the concentration of o-xylene after infiltration. While the reason for this increase is not known, and may have been due to some artifact of the study, the results do indicate that xylene is easily transported by infiltrating water.

#### 21.2.1.2 Sorption on Soils

The mobility of xylene in the soil/ground-water system (and its eventual migration into aquifers) is strongly affected by the extent of its sorption on soil particles. In general, sorption on soils is expected to:

- increase with increasing soil organic matter content;
- increase slightly with decreasing temperature;
- increase moderately with increasing salinity of the soil water; and
- decrease moderately with increasing dissolved organic matter content of the soil water.

Based upon its octanol-water partition coefficient of 1450 (average for the 3 isomers), the soil sorption coefficient ( $K_{oc}$ ) is estimated to be 691. This number is indicative of moderate sorption potential.

#### 21.2.1.3 Volatilization from Soils

Transport of xylene vapors through the air-filled pores of unsaturated soils is an important transport mechanism for near-surface soils. In general, important soil and environmental properties influencing the rate of volatilization include soil porosity, temperature, convection currents and barometric pressure changes; important physicochemical properties include the Henry's law constant, the vapor-soil sorption coefficient, and, to a lesser extent, the vapor phase diffusion coefficient (31).

#### 21.2.2 Transformation Processes in Soil/Ground-water Systems

The persistence of xylene in soil/ground-water systems has not been studied. In most cases, it should be assumed that the chemical will persist for months to years (or more).

Xylene under normal environmental conditions is not expected to undergo hydrolysis since it contains no hydrolyzable functional groups (529).

No information on the biodegradability of xylene in the soil/ground-water environment is available. However, based upon data for other structurally-similar chemicals (e.g., toluene, ethyl benzene), it is expected that xylene would be biodegradable. The importance of biodegradation as a fate pathway would, of course, depend upon the type and concentration of microorganisms present as well as many other environmental factors.

### 21.2.3 Primary Routes of Exposure From Soil/Ground-water Systems

The above discussion of fate pathways suggests that the xylene isomers are highly volatile from aqueous solutions, moderately adsorbed by soil and have a moderate potential for bioaccumulation. The xylene isomers may volatilize from soil surfaces. The portion not removed by volatilization may eventually migrate to ground water. These fate characteristics suggest several potential exposure pathways.

Volatilization of xylenes from a disposal site, particularly during drilling or restoration activities, could result in inhalation exposures. In addition, there is a potential for ground water contamination, particularly in sandy soil. Mitre (83) reported that xylene has been found at 40 of the 546 National Priority List (NPL) sites. It was detected at 30 sites in ground water, 8 sites in surface water and 8 sites in air.

This compound was reported in the USEPA (531) Ground Water Supply Survey (GWSS). This survey examined 945 finished water supplies that use ground-water sources. The results for the xylene isomers are summarized below:

| Sample Type                                   | Occurrences* |     | Median<br>of Positives<br>( $\mu\text{g/L}$ ) | Maximum<br>( $\mu\text{g/L}$ ) |
|---|--------------|-----|---|--------------------------------|
|   | No.          | %   |   |                                |
| <u>m-Xylene</u>                               |              |     |   |                                |
| Random  |              |     |   |                                |
| Supplies serving <10,000 people (280 samples) | 6            | 2.1 | 0.32  | 1.5                            |
| Supplies serving >10,000 people (186 samples) | 2            | 1.1 | 0.59  | 0.91                           |
| Non-Random                                    |              |     |   |                                |
| Supplies serving <10,000 people (321 samples) | 8            | 2.5 | 0.38  | 0.83                           |
| Supplies serving >10,000 people (158 samples) | 0            | 0   | -   | -                              |
| <u>o- and p-Xylene</u>                        |              |     |   |                                |
| Random  |              |     |   |                                |
| Supplies serving <10,000 people (280 samples) | 6            | 2.1 | 0.34  | 0.59                           |
| Supplies serving >10,000 people (186 samples) | 2            | 1.1 | 0.59  | 0.91                           |
| Non-Random                                    |              |     |   |                                |
| Supplies serving <10,000 people (321 samples) | 10           | 3.1 | 0.44  | 2.5                            |
| Supplies serving >10,000 people (158 samples) | 0            | 0   | -   | -                              |

\*Samples having levels over quantification limit of 0.2  $\mu\text{g/L}$ .



The random results are intended to statistically represent the U.S. ground-water drinking water supplies. The non-random samples were chosen by the states as being potentially contaminated. Xylenes have also been detected in the National Organic Monitoring Survey (NOMS) (90).

The properties and the survey results described above indicate that xylenes have the potential for movement in soil/ground-water systems. These compounds may eventually reach surface waters by this mechanism, suggesting several other exposure pathways:

- Surface waters may be used as drinking water supplies, resulting in direct ingestion exposure;
- Aquatic organisms residing in these waters may be consumed, also resulting in ingestion exposures;
- Recreational use of these waters may result in dermal exposures;
- Domestic animals may consume or be dermally exposed to contaminated ground or surface waters; the consumption of meats and poultry could then result in ingestion exposures.

In general, exposures associated with surface water contamination can be expected to be lower than exposure from drinking contaminated ground water for two reasons. First, the Henry's law constants for xylenes suggest that volatilization will occur upon reaching surface waters. Secondly, the BCF for xylene is not high enough to suggest consumption of aquatic organisms or domestic animals as a significant source of exposure compared to drinking water.

#### 21.2.4 Other Sources of Exposure

The volatility of xylenes suggest that they may be found in air. Brodzinsky and Singh (84) compiled all available atmospheric data for a number of volatile organics. For xylenes, they had data for o-xylene and m/p-xylene. For o-xylene, they had data for 2182 locations. For rural and remote areas, the median concentration of o-xylene was 0.4  $\mu\text{g}/\text{m}^3$ . In urban and suburban areas, the median was 5.2  $\mu\text{g}/\text{m}^3$ , and in source-dominated areas, the median was 3.5  $\mu\text{g}/\text{m}^3$ . For m/p-xylene, the median concentration for rural and remote areas was 0.38  $\mu\text{g}/\text{m}^3$ . In urban and suburban areas, the median was 12  $\mu\text{g}/\text{m}^3$ , and in source-dominated areas, the median was 7.4  $\mu\text{g}/\text{m}^3$ . These results suggest inhalation exposures even in rural and remote areas.

Xylene is found in drinking water obtained from ground water. There is a lack of data on the occurrence of xylenes in finished surface water supplies. Discharge of effluents contaminated with xylenes near water intakes in surface water could potentially result in ingestion exposures from drinking water. The use of this compound as a solvent in a variety of consumer products suggest that direct dermal and inhalation exposures may occur during consumer use.

### 21.3 HUMAN HEALTH CONSIDERATIONS

#### 21.3.1 Animal Studies

##### 21.3.1.1 Carcinogenicity

Xylene (commercial mixture), administered to rats and mice by gavage, has been tested for carcinogenicity by NTP (594); the histopathological results are not yet available. Dosage levels administered were 250 and 500 mg/kg for rats, 500 and 100 mg/kg for mice.

##### 21.3.1.2 Mutagenicity

Xylenes have been tested for mutagenicity in both bacterial and mammalian systems and have shown fairly conclusive evidence for the absence of mutagenic activity. Xylene failed to induce sister chromatid exchange in cultured human lymphocytes (798) and produced no evidence of bone marrow chromosome damage in rats exposed to technical-grade xylene by inhalation at 300 ppm, 6 hours per day, 5 days per week for up to 18 weeks (799). The ortho-, meta- and para-isomers of xylene gave negative results in the Salmonella microsome assay (795). Technical-grade xylene was also inactive in DNA repair assays with E. coli and B. subtilis (796,797). Technical-grade xylene (which contains 18.3% v/v ethyl benzene) did induce a low frequency of recessive lethals in Drosophila; the orth- and meta-isomers of xylene alone, as well as ethyl benzene alone, were negative in this assay (799).

##### 21.3.1.3 Teratogenicity, Embryotoxicity and Reproductive Effects

A study assessing the teratogenicity of the xylene isomers was conducted by Ungvary et al. (212). Rats were exposed by inhalation to 35, 350 or 700 ppm of ortho-, meta-, or para-xylene continuously on days 7 through 14 of gestation. The incidence of visceral, skeletal and external abnormalities was not affected by any of the isomers leading the authors to conclude that xylene was not a teratogen. Decreased fetal development was observed at the highest exposure level for all 3 isomers. This was attributed to the decrease in maternal food intake at that level. Additional groups of rats were exposed to

the same vapor concentrations but only to o-xylene for 2 hours on the 18th day of gestation. The o-xylene was found to cross the placenta and was present in the fetal blood and amniotic fluid.

In a study conducted with CD-1 mice, a commercial mixture of xylene was administered by gavage (in 3 divided doses daily) at dosages of 0, 520, 1030, 2060, 2580, 3100 or 4130 mg/kg/day on days 6-15 of gestation. The commercial mixture, administered in cottonseed oil, consisted of 9.1% o-, 60.2% m-, 13-6% p-xylene and 17% ethyl benzene. No effects were observed in either the dams or fetuses exposed to a level of 1030 mg/kg/day or less. At exposures of 2060 mg/kg/day and higher, doses approaching lethal levels in the dams, fetal weight was significantly decreased and the average percentage of malformed fetuses was increased; cleft palate was the major malformation noted (794).

#### 21.3.1.4 Other Toxicologic Effects

Early animal experiments indicated xylene induced changes in the blood and bone marrow. These older findings have little significance, and have not been reported here, because the xylene used at that time was contaminated with benzene and other hydrocarbons. Recent studies strongly support the conclusion that uncontaminated xylene does not have myelotoxic effects (599).

##### 21.3.1.4.1 Short-term Toxicity

Acute exposure to xylene primarily affects the central nervous system. No signs of CNS impairment were observed in rats and mice after a 4-hour exposure to vapor concentrations ranging from 510 to 800 ppm. Animals exposed to 1350 ppm for 2 hours exhibited poor coordination which disappeared shortly after exposure ceased. Higher concentrations of xylene (7000 ppm), cause initial symptoms of excitement which are followed by depression and death due to respiratory paralysis (70). An  $LC_{50}$  value of 500 ppm·4 hr and an oral  $LD_{50}$  value of 4300 mg/kg have been reported for rats (47).

Acute liver injury was found in guinea pigs who were administered 1 to 2 g xylene/kg body weight intraperitoneally while rats exposed to vapor concentrations ranging from 1000 to 2000 ppm for 4 hours exhibited hepatotoxic effects which were inferred from increased serum enzyme activities (70).

Corneal vacuoles were observed in cats exposed for several hours to xylene vapor concentrations that were just sublethal. The vacuoles disappeared when xylene exposure was discontinued (599, 19). Two drops of xylene instilled into rabbits' eyes produced slight conjunctival irritation with very slight but transient, corneal injury (19,599).

Repeated application of undiluted xylene to rabbit skin produced moderate irritation and necrosis (12).

#### 21.3.1.4.2 Chronic Toxicity

Studies in animals indicate that xylene has a relatively low toxicity over the long-term. No changes were found in rats, guinea pigs, dogs and monkeys continuously exposed to 80 ppm for 127 days, nor in rats exposed to 700 ppm for 130 days (70). Another investigator reported behavioral changes in rats exposed by inhalation to 300 ppm, 6 hours a day for 5 to 18 weeks (70). Slight inflammation, congestion and necrosis of the kidney tubules were found in rabbits exposed by inhalation to 700 ppm, 8 hours daily, 6 days per week for 130 days (70). Repeated exposure of rabbits to 1150 ppm for 40 to 55 days caused a reversible decrease in red and white blood cell count and an increase in platelets (70).

#### 21.3.2 Human and Epidemiologic Studies

##### 21.3.2.1 Short-term Toxicologic Effects

Xylene has narcotic effects on the central nervous system, variable effects on the liver and kidneys and irritant effects on the gastrointestinal tract (599).

NIOSH reports one incident of an accidental ingestion of a "small amount" of paint thinner composed of xylene (90%) and toluene. Several acetate impurities were also present. There was serological evidence of toxic hepatitis but the victim recovered within 20 days (599).

One fatality has been attributed to the inhalation of xylene vapors. Morley et al. (617) described an incident in which 3 painters were overcome by xylene vapors; the concentration was estimated to be 10,000 ppm. It is not known how long it took the men to lose consciousness because they were not found until 18.5 hours later. An autopsy conducted on one worker who was found dead revealed pulmonary edema, liver congestion and brain hemorrhages. The two surviving workers suffered from amnesia and hepatic impairment; one had evidence of temporary renal impairment. Both recovered within 2 days.

Exposure of human subjects to 90 ppm of m-xylene produced impairment of reaction time, manual coordination and body balance. Although tolerance to these effects developed over one work-week, it was largely lost over a weekend (17).

Brief exposure to 200 ppm causes irritation of the eyes, nose and throat (38). Workers exposed to concentrations above 200 ppm complained of nausea, vomiting, abdominal pain and loss of appetite (9). A recent report noted that artists as well as others who employ felt-tip-marker pens for extended periods of time in enclosed rooms may develop symptoms of nausea, dizziness and headache which can be attributed to xylene exposure; xylene is used as an ink solvent in these products (618).

Xylenes have been reported to cross the human placenta (43). Incomplete brain development has been reported in children whose mothers had been exposed to xylene, toluene and white spirit (59).

Xylene is a skin irritant and causes redness, dryness and defatting. Prolonged skin contact may cause the formation of vesicles (46). Absorption of liquid xylene through intact skin occurs readily and has been estimated to occur at a rate of 4.5-9.6 mg/cm<sup>2</sup>/hr (599).

An accidental splash of xylene into the eye causes only transient superficial damage with rapid recovery (19). Corneal vacuoles were reported in workers exposed to "practically pure" xylene vapors (concentration unspecified) for 2-3 days. Recovery occurred 8 to 11 days after exposure ceased. It is not known whether this effect is totally reversible on intermittent exposure or whether it may lead to permanent damage (19,599).

#### 21.3.2.2 Chronic Toxicologic Effects

The effects of long-term xylene exposure resemble those from acute exposure, but more severe. Headache, irritability, fatigue, digestive disorders and sleep disorders have been reported (70). Inhalation of high concentrations of xylene vapors may produce CNS excitation, followed by depression and characterized by paresthesia, tremors, apprehension, impaired memory, weakness, vertigo, headache and anorexia (12). No bone marrow aplasia, but hyperplasia, moderate liver enlargement, necrosis and nephrosis may occur (12).

#### 21.3.3 Levels of Concern

In the absence of formal drinking water standards, the USEPA (383) developed Health Advisories for xylene levels in drinking water. They are: 1 day - 12 mg/L; 10 days - 1.4 mg/L; and long-term - 0.62 mg/L.

Both OSHA (298) and the ACGIH (3) have set an occupational exposure limit of 100 ppm (435 mg/m<sup>3</sup>) for xylene.

#### 21.3.4 Hazard Assessment

Data on the effects of long-term human exposure to xylene are primarily high-level occupational inhalation exposures which have resulted in CNS effects, incoordination, nausea, vomiting and abdominal pain. Short-term inhalation exposures are associated with narcotic effects on the central nervous system. Ingestion data are almost completely lacking.

Studies in laboratory animals suggest xylene has a relatively low chronic toxicity. Some data suggest possible kidney and liver impairment with high level (>1000 ppm) inhalation exposures. No data are currently available regarding the carcinogenic activity of xylene. Available evidence indicates an absence of mutagenic activity for xylene. One study in rats indicated xylene was not a teratogen in that species, while another study in mice indicated an increased incidence of cleft palates but only at doses which approached lethal levels for the dams; ingestion of up to 1030 mg/kg/day produced no adverse effects.

A definitive assessment of the human health hazards associated with long-term, low-level ingestion of xylene cannot be made in the absence of data on carcinogenic potential. However, human experience with xylene in the industrial sector provides no indications of major health concerns associated with xylene exposure.

#### 21.4 SAMPLING AND ANALYSIS CONSIDERATIONS

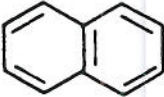
Determination of the concentrations of xylenes in soil and water requires collection of a representative field sample and laboratory analysis. Due to the volatility xylenes, care is required to prevent losses during sample collection and storage. Soil and water samples should be collected in airtight containers with no headspace; analysis should be completed within 14 days of sampling. In addition to the targeted samples, quality assurance samples such as field blanks, duplicates, and spiked matrices should be included in the analytical program.

Xylenes are not included among the EPA-designated priority pollutants. However, EPA Methods 602, 624, and 1624 (65) would be appropriate methods of choice for the analysis of xylenes in aqueous samples. An inert gas is bubbled through the aqueous sample in a purging chamber at ambient temperature, transferring the xylenes from the aqueous phase to the vapor phase and onto a sorbent trap. The trap is then heated and backflushed to desorb the xylenes and transfer them onto a gas chromatographic (GC) column. The GC column is programmed to separate

the volatile organics; xylenes are then detected with a photo-ionization detector (Method 602) or a mass spectrometer (Methods 624 and 1624).

The EPA procedures recommended for xylene analysis in soil and waste samples, Methods 8020 and 8240 (63), differ from the aqueous procedures primarily in the method by which the analyte is introduced into the GC. The recommended method involves dispersing the soil or waste sample in methanol or polyethylene glycol to dissolve the xylenes. A portion of the solution is then combined with water and purged as described above. Other sample introduction techniques include direct injection and a headspace method.

Xylene detection limits for the various methods were not determined but would be in the range of 1-10  $\mu\text{g/L}$  for aqueous samples and 1  $\mu\text{g/g}$  for non-aqueous samples.

|  |                          |   |   |
|--|--------------------------|---|---|
| COMMON SYNONYMS:<br>Naphthene<br>White tar<br>Tar camphor<br>Mothballs | CAS REG. NO.:<br>91-20-3 | FORMULA:<br>$C_{10}H_8$   | AIR W/V CONVERSION<br>FACTORS at 25°C (12)  |
|  | NIOSH NO.:<br>QJ0525000  | STRUCTURE:<br> | 5.24 mg/m <sup>3</sup> $\approx$ 1 ppm<br>0.191 ppm $\approx$ 1 mg/m <sup>3</sup> |
|  |                          |   | MOLECULAR WEIGHT:<br>128.16   |

|            |   |
|------------|---|
| REACTIVITY | Naphthalene may generate heat, react vigorously, and possibly ignite or explode in contact with oxidizing mineral acids or other strong oxidizing agents (511,505). |
|------------|---|

|                       |   |
|-----------------------|---|
| PHYSICO-CHEMICAL DATA | <ul style="list-style-type: none"> <li>● Physical State (at 20°C): volatile crystalline flakes (23)</li> <li>● Color: white (23)</li> <li>● Odor: "moth balls" or coal tar (54,59)</li> <li>● Odor Threshold: 0.084 ppm (384)</li> <li>● Liquid Density (g/ml at 20°C): 1.145 (14)</li> <li>● Freezing/Melting Point (°C): 80.2 (23)</li> <li>● Boiling Point (°C): 218 (23)</li> <li>● Flash Point (°C): 79 (closed cup) (21)</li> <li>● Flammable Limits in Air, % by Volume: 0.9-5.9 (51,38,506)</li> <li>● Autoignition Temperature (°C): 526-567 (51,38,506)</li> <li>● Vapor Pressure (mm Hg at 20°C): 0.053 (30)</li> <li>● Saturated Concentration in Air (mg/m<sup>3</sup> at 20°C): 375 (ADL estim)</li> <li>● Solubility in Water (mg/L at 20°C): 31.7 (440)</li> <li>● Viscosity (cp): 0.754 at 100°C (21)</li> <li>● Surface Tension (dyne/cm): 31.8 at 100°C (59)</li> <li>● Log (Octanol-Water Partition Coefficient), log K<sub>ow</sub>: 3.30 (29)</li> <li>● Soil Adsorption Coefficient, K<sub>oc</sub>: 962 (652)</li> <li>● Henry's Law Constant (atm·m<sup>3</sup>/mol at 25°C): 4.82 x 10<sup>-4</sup> (74)</li> <li>● Bioconcentration Factor: 44 (blue mussel), 77 (sand dab); 95 (estim) (439,659)</li> </ul> |
|-----------------------|---|



|   |   |   |  |
|---|---|---|--|
| PERSISTENCE<br>IN THE SOIL-<br>WATER SYSTEM                         | Naphthalene is expected to be fairly mobile in the soil/ground-water system. Transport with infiltrating water is expected to be important, particularly in sandy soils and soils of low organic content. Volatilization may be important at the surface. Biodegradation has been shown to occur with acclimated microbial populations and under aerobic conditions; biodegradation in natural soils and ground water is not expected to be significant.  |   |  |
| PATHWAYS<br>OF<br>EXPOSURE  | The primary pathway of concern from the soil-water system is the migration of naphthalene to ground-water drinking water supplies. There is some evidence that migration from disposal sites to ground water and surface water has occurred in the past. Inhalation exposures resulting from volatilization from surface soils may also occur.  |   |  |
| HEALTH<br>HAZARD<br>DATA  | <p><u>Signs and Symptoms of Short-term Human Exposure (54):</u><br/>Ingestion or inhalation of naphthalene causes eye irritation, headache, nausea, vomiting, sweating and abdominal pain. Skin contact may cause redness and dermatitis. Both the vapor and the solid are irritating to the eye.</p> <p><u>Toxicity Based on Animal Studies:</u></p> <table data-bbox="358 1031 1382 1146"> <tr> <td data-bbox="358 1031 911 1146">LD<sub>50</sub> (mg/kg)<br/>oral [rat] 1780 (59)<br/>skin -- no data</td> <td data-bbox="915 1031 1382 1146">LCLo (mg/m<sup>3</sup>)<br/>inhalation -- no data</td> </tr> </table> <p>Long-Term Effects: No significant changes</p> <p>Pregnancy/Neonate Data: Negative</p> <p>Mutation Data: Negative</p> <p>Carcinogenicity Classification: NTP - none assigned; IARC - none assigned</p> | LD <sub>50</sub> (mg/kg)<br>oral [rat] 1780 (59)<br>skin -- no data | LCLo (mg/m <sup>3</sup> )<br>inhalation -- no data |
| LD <sub>50</sub> (mg/kg)<br>oral [rat] 1780 (59)<br>skin -- no data | LCLo (mg/m <sup>3</sup> )<br>inhalation -- no data  |   |  |
| HANDLING<br>PRECAUTIONS<br>(38)                                     | Handle chemical only with adequate ventilation • Vapor concentrations of 10-500 ppm: any supplied-air respirator or self-contained breathing apparatus with full facepiece; chemical cartridge respirator with full facepiece, organic vapor cartridge and dust filter • Above 500 ppm: self-contained breathing apparatus with full facepiece operated in positive-pressure mode • Chemical goggles if there is probability of eye contact • Protective clothing to prevent prolonged or repeated skin contact.  |   |  |
| EMERGENCY<br>FIRST AID<br>TREATMENT<br>(54)                         | <u>Ingestion:</u> Induce vomiting if victim is conscious • <u>Inhalation:</u> Move victim to fresh air. Give artificial respiration if necessary • <u>Skin:</u> Remove contaminated clothing. Wash skin with soap and water • <u>Eye:</u> Irrigate with large amounts of water.   |   |  |

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## ENVIRONMENTAL AND OCCUPATIONAL STANDARDS AND CRITERIA

AIR EXPOSURE LIMITS:Standards

- OSHA PEL (8-hr TWA): 10 ppm
- AFOSH PEL (8-hr TWA): 10 ppm; STEL (15-min): 15 ppm

Criteria

- NIOSH IDLH (30-min): 500 ppm
- ACGIH TLV® (8-hr TWA): 10 ppm
- ACGIH STEL (15-min): 15 ppm

WATER EXPOSURE LIMITS:Drinking Water Standards

None established

EPA Health Advisories

None established

EPA Ambient Water Quality Criteria (355)

- Human Health  
No criterion established due to insufficient data.
- Aquatic Life
  - Freshwater species  
acute toxicity: no criterion, but lowest effect level occurs at 2300 µg/L.  
  
chronic toxicity: no criterion, but lowest effect level occurs at 620 µg/L.
  - Saltwater species  
acute toxicity: no criterion, but lowest effect level occurs at 2350 µg/L.  
  
chronic toxicity: no criterion established due to insufficient data.

## REGULATORY STATUS (as of October 1, 1985)

Promulgated Regulations

## ● Federal Programs

Clean Water Act (CWA)

Naphthalene is designated a hazardous substance under CWA. It has a reportable quantity (RQ) limit of 45.4 kg (347,556). It is also listed as a toxic pollutant (351). Water quality criteria have been set for aquatic life. Guidelines exist for naphthalene effluent in the iron and steel manufacturing industry (354).

Safe Drinking Water Act (SDWA)

In states with an approved Underground Injection Control program, a permit is required for the injection of naphthalene-containing wastes designated as hazardous under RCRA (295).

Resource Conservation and Recovery Act (RCRA)

Naphthalene is identified as a toxic hazardous waste (U165) and listed as a hazardous waste constituent (328,329). A non-specific source of naphthalene-containing waste is the production of chlorinated aliphatic hydrocarbons (325). Waste streams from the following industries contain naphthalene and are listed as specific sources of hazardous wastes: wood preservation (creosote and/or pentachlorophenol preserving processes), pesticides (creosote production) and coking (operational residues) (326,327).

Comprehensive Environmental Response Compensation and Liability Act (CERCLA)

Naphthalene is designated a hazardous substance under CERCLA. It has a reportable quantity (RQ) limit of 45.4 kg. Reportable quantities have also been issued for RCRA hazardous waste streams containing naphthalene but these depend upon the concentration of the chemicals in the waste stream (556).

Occupational Safety and Health Act (OSHA)

Employee exposure to naphthalene in any 8-hour work-shift of a 40-hour work-week shall not exceed an 8-hour time-weighted-average (TWA) of 10 ppm (298).

Hazardous Materials Transportation Act (HMTA)

The Department of Transportation has designated naphthalene as a hazardous material which is subject to requirements for packaging, labeling and transportation (306).

## ● State Water Programs

All states follow EPA Ambient Water Quality Criteria.

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