United States
Environmental Protection
Agency

Pollution Prevention
and Toxics
(7407)

December 1994
EPA 749-F-95-019a

OPPT Chemical Fact Sheets

(Styrene) Fact Sheet: Support Document
(CAS No. 100-42-5)

This summary is based on information retrieved from a systematic search limited to secondary sources (see Appendix A). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of styrene are summarized in Table 1.

TABLE 1. CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF STYRENE

Characteristic/Property	Data	Reference
CAS No.	100-42-5	
Common Synonyms	vinyl benzene; phenylethene; ethenyl benzene; cinnamene	Keith and Walters 1987
Molecular Formula	C_8H_8	
Chemical Structure	$C_6H_5CH=CH_2$	
Physical State	colorless to yellowish oily liquid	Keith and Walters 1987
Molecular Weight	104.14	Budavari et al. 1989
Melting Point	-30.6°C	Budavari et al. 1989
Boiling Point	145-146°C	Budavari et al. 1989
Water Solubility	310 mg/L at 25°C	Howard 1989
Density	0.9059 g/mL at 20°C	Keith and Walters 1987
K_{OC}	920 (calculated)	CHEMFATE 1994
Log K_{OW}	2.95 (measured)	Hansch and Leo 1979
Vapor Pressure	5 mmHg at 20°C	Verschueren 1983
Reactivity	readily polymerizes when heated or exposed to light; releases heat and may be explosive	Keith and Walters 1987
Flash Point	31°C	
Henry's Law Constant	2.75×10^{-3} atm·m^3/mol	CHEMFATE 1994
Fish Bioconcentration Factor	13.5 (goldfish)	Howard 1989
Odor Threshold	0.036 mg/m^3	Verschueren 1983
Conversion Factors	1 ppm = 4.33 mg/m^3 1 mg/m^3 = 0.23 ppm	Verschueren 1983

II. PRODUCTION, USE, AND TRENDS

A. Production

Mannsville (1993) lists 9 producers of styrene in the United States in 1992 (see Table 2). In 1993, the U.S. production volume of styrene was 10.07 billion pounds (Chemical and Engineering News 1994). This was an 11.8 percent increase from the 1992 production volume of approximately 9 billion pounds (4 billion kilograms)(Chemical and Engineering News 1994). The U.S. imported 552 million pounds and exported 1,598 million pounds of styrene in 1992 (see Table 5).

TABLE 2. U.S. PRODUCERS OF STYRENE AND THEIR CAPACITIES IN 1993

Producer[1]	Plant Location	Plant Capacity (Millions of Pounds)
Amoco	Texas City, TX	840
Arco	Channelview, TX	2,525
Chevron Chemical Company	St. James, LA	1,500
Cos-Mar (Fina/GE Plastics)	Carville, LA	1,900
Dow	Freeport, TX	1,500
Huntsman Chemical	Bayport, TX	1,250
Rexene	Odessa, TX	320
Sterling Chemicals	Texas City, TX	1,600
Westlake	Lake Charles, LA	350
TOTAL		11,785

Source: Mannsville 1993.

[1] USITC (1994) lists three additional producers of styrene in 1992 as Deltech Corporation, which has an idle plant at Baton Rouge, LA (Mannsville 1993); Phillips 66 Company; and Union Carbide Corporation, Industrial Chemicals Division.

TABLE 3. U.S. PRODUCTION AND SALES OF STYRENE IN 1992

Production (Millions of Pounds)	Sales Quantity (Millions of Pounds)	Sales Value ($1,000s)	Average Unit Value (Per Pound)
8,980	3,742	917,914	$0.24

Source: USITC 1994.

B. Uses

The principal uses of styrene include the manufacture of plastics, synthetic rubber, resins, and insulators (HSDB 1994; Sax and Lewis 1987; Windholz 1983; see Table 4 for applicable SIC Codes). Styrene is used in the production of polystyrene, styrene-butadiene rubber (SBR), acrylonitrile-butadiene-styrene (ABS) and styrene-acrylonitrile-polymer resins [including styrene-acrylonitrile (SAN) resins]. It is also used in the manufacture of styrenated polyesters, rubber-modified polystyrene and copolymer resins; as an intermediate; and in the manufacture of protective surface coatings, including styrene-butadiene latex and alkyds (HSDB 1994; Sax and Lewis 1987).

Other applications include use: as a diluent to reduce viscosity of uncured resin systems; in glass fiber-reinforced, unsaturated polyester resins used in construction materials and boats; in the synthesis of styrene-divinylbenzene copolymers as a matrix for ion-exchanging resins; as cross-linking agent in unsaturated polyester resin manufacture; in rubber articles, when intended for use in contact with food; and as an FDA-approved synthetic flavoring agent and adjuvant for ice cream and candy (Mannsville 1993). It is also a monomer for straight and impact polystyrene; comonomer for styrene-butadiene elastomers and for other copolymers including acrylic ester-styrene; chemical intermediate for styrenated phenols and styrene oxide, and styrenated oils (Mannsville 1993).

TABLE 4. END USE PATTERN OF STYRENE--1993 ESTIMATE

Derivative (Typical Standard Industrial Classification (SIC) Code)[2]	**U.S Consumption** (Millions of Pounds)	**Percentage of U.S. Use**
Polystyrene (SIC 2821)	5,366	66
SBR Elastomer and SB Latex (SIC 2822)	976	12
ABS and SAN Resins (SIC 2821)	894	11
Unsaturated Polyester (SIC 2821)	407	5
Miscellaneous (Various SICs)	487	6
TOTAL	8,130	100

Source: Mannsville 1993.

[2] The Standard Industrial Classification (SIC) code is the statistical classification standard for all Federal economic statistics. The code provides a convenient way to reference economic data on industries of interest to the researcher. SIC codes presented here are not intended to be an exhaustive listing; rather, the codes listed should provide an indication of where a chemical may be likely to be found in commerce.

C. Trends

The production of styrene has steadily increased each year since 1990 (see Table 5). From 1988 to 1993, the production volume increased 2.3 percent on an average annual basis; it increased on an average annual basis of 4 percent between 1983 and 1993 (Chemical and Engineering News 1994). The production volume increased 10.9 percent from 1991 to 1992 (Chemical and Engineering News 1994). Styrene demand is expected to grow about 2.5 to 3.5 percent each year over the next three years, reflecting the projected trend in polystyrene output because styrene consumption and distribution are mainly dependent on polystyrene demand (Grayson 1985; Mannsville 1993). Export markets are likely to decline as an outlet of U.S. production due to increased global competition. Currently, only about 20 percent of domestic ABS polymer output is exported. The consumption of styrene in the U.S. may further decline in the future due to the Clean Air Act mandate on reduction in the volume of allowable styrene emissions (Mannsville 1993).

TABLE 5. U.S. SUPPLY AND DEMAND FOR STYRENE (MILLIONS OF POUNDS)

Year	1990	1991	1992	1993 (Projected)	1995 (Projected)
Capacity	9,630	10,310	10,660	11,785	N/A
Production	8,017	8,114	8,942 (Projected)	N/A	N/A
Imports	641	572	552	N/A	N/A
Exports	864	1,610	1,598	N/A	N/A
Demand	7,794	7,080	7,896	8,130	8,550

N/A: Not available
Source: Mannsville 1993.

III. ENVIRONMENTAL FATE

A. Environmental Release

Of the total 32.8 million pounds of styrene released to the environment in 1992, as reported to the Toxics Release Inventory by certain types of U.S. industries, 32.4 million pounds were released into the atmosphere, 83 thousand pounds into underground injection sites, 23 thousand pounds into surface waters, and 304 thousand pounds onto land (TRI92 1994). Styrene has been detected in the water supply of Cincinnati, Ohio at a concentration of 0.024 ppb but not in 945 other finished water supplies throughout the U.S. (Howard 1989). The chemical was detected at concentrations of 100-200 ppb in well water adjacent to a landfill containing buried styrene in drums (Howard 1989). Concentrations of styrene ranging from 0.07 to 15 parts per billion (ppb) have been measured in the atmosphere of U.S. cities (Howard 1989). Besides industrial release, styrene is also released in automobile exhaust and cigarette smoke (Howard 1989).

B. Transport

Styrene is expected to volatilize from surface waters as predicted by its Henry's Law constant (Howard 1989). The chemical is also removed from waters by adsorption onto soils and sediments. Under certain conditions, styrene may leach through soil (particularly sandy soils) and enter ground water (Howard 1989, U.S. EPA 1984).

C. Transformation/Persistence

1. Air — In the atmosphere, styrene reacts with both hydroxyl radicals and ozone with estimated half-lives of 3.5 and 9 hours, respectively (Howard 1989). The chemical is also degraded in the presence of NO_X and natural sunlight. Smog chamber experiments with simulated sunlight and auto exhaust as a source of styrene, showed a 55% disappearance of styrene in 2 hours (U.S. EPA 1984).

2. Soil — Biodegradation is the major route of removal of styrene from soils. Microbes isolated from landfill soil degraded 95% of the styrene present in 16 weeks (Howard 1989, U.S. EPA 1984).

3. Water — Styrene rapidly volatilizes from surface water with estimated half-lives from a river or pond of 0.6 days and 13 days, respectively (U.S. EPA 1984). Microbes isolated from unadapted sewage sludge degraded 42% of the styrene present in 5 days while the microbial degradation with adapted sewage sludge was 80% in 5 days (U.S. EPA 1984).

4. Biota — Based on the fish bioconcentration factor of 13.5 (goldfish) and the water solubility of styrene, the chemical is not likely to accumulate in biological organisms (Howard 1989).

IV. HEALTH EFFECTS

A. Pharmacokinetics

1. Absorption — Styrene is absorbed into the body following oral or inhalation exposure. Complete absorption occurred in fasted rats given a total of 3.147 mg styrene by gavage in an aqueous solution (ATSDR 1992, U.S. EPA 1984). A peak blood level of 6 micrograms/mL was reached within minutes (ATSDR 1992). In humans exposed to styrene vapor, pulmonary retention is approximately 66% of the administered concentration; dermal absorption of styrene has been shown to be significantly less than absorption by the respiratory tract (ATSDR 1992).

2. Distribution — Following inhalation exposure, styrene is preferentially distributed to adipose tissue. Fat levels in rats were 10-times greater than levels in observed organs after exposure to 50-2000 ppm for 5 hours (ATSDR 1992). Following oral administration of 20 mg/kg of radiolabeled styrene to rats, the highest organ levels were found in the kidney, liver, and pancreas (U.S. EPA 1984).

3. Metabolism — Styrene is presumed to be metabolized to styrene oxide which is then converted to styrene glycol. Styrene glycol is metabolized to either mandelic acid or to benzoic acid and then hippuric acid. Mandelic acid is also metabolized to phenylglyoxylic acid (ATSDR 1992, U.S. EPA 1984). Minor metabolic pathways include the conjugation of styrene oxide with glutathione and the formation of vinyl phenol (ATSDR 1992).

4. Excretion — Urinary excretion is the major route of elimination of styrene. In humans, the main urinary metabolites are mandelic acid and phenylglyoxylic acid; rats also excrete hippuric acid and glucuronide (ATSDR 1992). Human volunteers exposed by inhalation to 50 to 200 parts per million (ppm) showed biphasic urinary elimination of mandelic acid with a half-life for the first phase of 4 hours and for the second phase of 25 hours (ATSDR 1992). Urinary metabolite concentrations have been correlated with exposure concentrations in humans (U.S. EPA 1994). Following an oral dose of 50 mg/kg radiolabeled styrene to rats, 95% of the label was recovered in the urine, 1% in expired air, and 4% in the feces over 72-hours (U.S. EPA 1984).

B. Acute Effects

Styrene vapor is irritating to the eyes and respiratory tract of humans and animals. Inhalation studies in animals indicate that styrene has low acute toxicity.

1. Humans — Eye and throat irritation occurred in human volunteers exposed to 376 ppm styrene for 1 hour and was accompanied by increased nasal secretion at exposures of 800 ppm for 4 hours (ATSDR 1992, U.S. EPA 1984). At the end of an 8-hour workshift, workers exposed to 212 ppm styrene had higher urinary levels of alanine-aminopeptidase and N-acetyl-glucosaminidase than unexposed workers, indicating potential renal effects of styrene (ATSDR 1992).

2. Animals — The oral LD_{50} of styrene for rats is approximately 5 g/kg (U.S. EPA 1984). An inhalation LC_{50} value as low as 2700 ppm for rats exposed for 4 hours has been reported (U.S. EPA 1984).

C. Subchronic/Chronic Effects

EPA has derived an oral reference dose (RfD[1]) for styrene of 0.2 mg/kg/day based on altered red blood cell parameters and liver effects in animals. Large oral doses to laboratory animals caused reduced weight gain and liver lesions. Repeated inhalation exposure to high concentrations of styrene resulted in degeneration of the olfactory epithelium of rats and mice. An inhalation RfC has been derived for styrene based on its neurotoxicity potential (Section IV G).

1. Humans — Workers engaged in the manufacture of styrene polymers with exposure to generally <1 ppm for 1-36 years had low erythrocyte counts and altered liver enzyme profiles. Blood and liver effects do not appear to be of concern for human exposures to styrene (ATSDR 1992). Occupational studies in humans show styrene to be a neurotoxicant; these results are described in Section IV G.

2. Animals — Beagle dogs were administered styrene by gavage at doses of 0, 200, 400, or 600 mg/kg/day for 560 days (U.S. EPA 1994). At the two highest doses, increased numbers of Heinz bodies in the red blood cells (RBC) and liver, decreased packed cell volume, increased iron deposits in the liver, and sporadic decreases in hemoglobin and RBC counts were observed. Based on these data the U.S. EPA (1994) has calculated a chronic RfD for styrene of 0.2 mg/kg/day.

[1]The RfD/RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during the time period of concern.

Rats given weekly doses of styrene by gavage at 500 mg/kg for 102 weeks showed liver, kidney, and stomach lesions; no effects were seen in mice (U.S. EPA 1994). Reduced weight gain and increased liver and kidney weights occurred in rats receiving 285 or 475 mg/kg/day for 185 days but no effects at 95 mg/kg/day (U.S. EPA 1994). Male and female rats were given 0, 1000, or 2000 mg/kg and male and female mice were given 0, 150, or 300 mg/kg by gavage for 78 weeks (NCI 1979). Reduced body weight occurred in both treated male rat groups, high-dose female rats, and both treated female mouse groups. In another study, male and female mice were treated weekly with 1350 mg/kg (U.S. EPA 1984). At 20 weeks, mortality was 50% and 20% for males and females, respectively accompanied by liver necrosis, splenic hypoplasia, and lung congestion.

Male and female mice were exposed to 0, 62.5, 125, 250, or 500 ppm styrene for 6 hours/day, 5 days/week for 13 weeks (U.S. EPA 1994). In both sexes the liver to body weight ratio was increased at the two highest doses; histopathology of the respiratory tract revealed metaplasia and degeneration of the olfactory epithelium of the nasal cavity at the lowest dose, necrosis at higher concentrations, and bronchiolar regeneration at all concentrations. Male and female rats exposed to 0, 125, 500, 1000, or 1500 ppm on the same schedule had increased liver to body weight ratios at the three highest levels in males and the two highest levels in females; degeneration of the olfactory epithelium occurred in both sexes at $\geq$ 1000 ppm (U.S. EPA 1994).

Pathological changes were observed in the respiratory mucosa of rats following exposure to 1000 ppm 4 hours/day, 5 days/week for 3 weeks (ATSDR 1992).

D. Carcinogenicity

The evidence for carcinogenicity of styrene is limited. IARC has classified styrene as Group 2B, possible human carcinogen, based on inadequate evidence in humans and on limited evidence in animals. EPA is currently reviewing the potential of styrene to cause cancer.

1. Humans — Several studies have reported an increase in leukemia and lymphoma among workers in the styrene manufacturing industry. However, the studies were inadequate because multiple chemical (e.g., benzene and butadiene) exposures were not addressed (IARC 1979, U.S.EPA 1984, ATSDR 1992). IARC classified styrene as Group 2B, possible human carcinogen (ATSDR 1992).

2. Animals — Limited cancer evidence of styrene in laboratory animals is presented in IARC (1979). The evidence comes from two gavage studies, conducted by the same laboratory, in which styrene dissolved in olive oil was administered to pregnant mice and their offspring. The first study administered a single 1350 mg/kg bw styrene dose to 29 pregnant O_{20} mice and weekly doses for up to 16 weeks of the same amount to 84 offspring (45 males and 39 females). No differences in tumor incidences were observed in the treated mothers relative to controls. Lung tumors (adenomas and adenocarcinomas) were observed in 20/23 male offspring and 32/32 female offspring, compared with 8/19 and 14/21 in olive oil controls and 34/53 and 25/47 untreated controls. No differences in tumor incidences were observed at sites other than the lung. The second study administered a single 300 mg/kg bw styrene dose to 15 pregnant C57 black mice and weekly doses for up to 120 weeks of the same amount to 54 offspring (27 males and 27 females). Lymphomas were observed in 10/12 mothers, compared to 3/5 in controls. Liver tumors (hepatocellular carcinomas) were observed in 3/24 male offspring, compared with 1/12 in olive oil controls. No differences in tumor incidences were observed at other sites in either mothers or progeny.
Lung adenomas and carcinomas were observed in mice treated with 300 or 1350 mg/kg/day for 100 days (U.S. EPA 1984, ATSDR 1992).

Rats (1000 or 2000 mg/kg/day) and mice (150 or 300 mg/kg/day) were administered styrene by gavage for 78 weeks. Additional rats were given 500 mg/kg/day for 103 weeks (NCI 1979). There were no significant increases in any tumor type for male or female rats and female mice. Male mice had an increased incidence of alveolar/bronchiolar carcinomas and adenomas as compared to study controls, but this increase was only slightly above historical control levels

(NCI 1979). NCI (1979) concluded that, under the conditions of the study, no convincing evidence for the carcinogenicity of styrene was obtained in rats or mice of either sex.

Inhalation exposure to 600 or 1000 ppm resulted in an increase in mammary adenocarcinomas in female rats at 600 ppm only. An increase in leukemia-lymphosarcomas was seen in females at both dose levels but was only significant when compared to historical control incidence rates (U.S. EPA 1988a). No brain tumors were found in rats exposed to 300 ppm 4 hours/day, 5 days/week, for 52 weeks (ATSDR 1992, U.S. EPA 1984).

E. Genotoxicity

Styrene was negative for reverse mutation in several strains of *Salmonella typhimurium* without metabolic activation, but both positive and negative results were obtained with metabolic activation (U.S. EPA 1988a). Mixed results were also obtained in mammalian clastogenic assays (U.S. EPA 1988a) and mutagenicity assays with eukaryotic organisms (U.S. EPA 1984). An increased frequency of chromosomal aberrations has been reported in male mice exposed by inhalation to 300 ppm styrene 6 hours/day for 5 days/week for 2 to 11 weeks (IARC 1979).

F. Developmental/Reproductive Toxicity

Epidemiological studies of the developmental and reproductive toxicity of styrene among women factory workers have been inconclusive. Increased fetal death has been seen in laboratory animal species (the mouse), exposed by inhalation to high, maternally toxic concentrations.

1. Humans — Birth weights of the offspring among female workers exposed to styrene in the plastics industry was compared. A 4% lower birth weight was detected in babies from women who worked at the most highly- exposed jobs (estimated at 82 ppm), although the difference was not statistically significant (ATSDR 1992, U.S. EPA 1994). Some studies have suggested an increased risk of spontaneous abortion among female workers, but other studies have been negative (ATSDR 1992).

2. Animals — Styrene was administered to pregnant rats by gavage at doses of 0, 90, or 150 mg/kg, 2 times/day on gestation days 6-15. Maternal body weight gain and food consumption was reduced on days 6 to 9 but no treatment-related effects were observed for any developmental toxicity parameters (U.S. EPA 1984).

   Pregnant rats and rabbits were exposed by inhalation to 0, 300, or 600 ppm styrene 7 hours/day on gestation days 6-15 (rats) and 6-18 (rabbits). Maternal toxicity (decreased weight gain and food consumption) was evident only for the first three days of dosing; no developmental toxicity occurred in either species (U.S. EPA 1994). Mice had increased maternal and fetal death rates after maternal exposure to 500 or 700 ppm on gestation days 6-15 for 6 hours/day (U.S. EPA 1994).

   Rats were exposed to 0, 125, or 250 ppm styrene in the drinking water for three generations. Reduction in survival was observed in high-dose F1 and F2 pups but the F3 generation was unaffected (U.S. EPA 1994).

G. Neurotoxicity

U.S. EPA has calculated an inhalation reference concentration (RfC; see footnote 1, p. 4) for styrene of 1 mg/m^3 (0.23 ppm), based on impaired neurological function of human workers. Alterations in vision, hearing loss, and longer reaction times have been associated with styrene exposure in the workplace.

1. Humans — The RfC was calculated from an epidemiological study (U.S. EPA 1994). Fifty workers with an average exposure duration of 8.6 years to concentrations ranging from 10 to 300 ppm (43 to 1278 mg/m^3) were given a battery of neurophysiological tests for CNS dysfunction.

Increases in reaction times and decreases in memory/concentration correlated to both exposure concentration and duration of exposure. Urinary metabolite concentrations of mandelic acid and phenylglyoxylic acid correlated to exposure concentration and depressed CNS function. Based on these data the U.S. EPA (1994) calculated a chronic RfC for styrene of 1 mg/m^3 (0.23 ppm).

Human volunteers exposed to 370-591 mg/m^3 (85.1-135.93 ppm) for 80 minutes had alterations in visual suppression and saccade (rapid, intermittent eye movements) tests when compared to unexposed controls (U.S. EPA 1994). The concentration of 370 mg/m^3 is roughly equivalent to 8.88 mg/kg over the 80 minute period[2].

Boat builders occupationally exposed for an average of 10.8 years to 50-140 mg/m^3 styrene showed alterations in the vestibuloocular reflex (U.S. EPA 1994). Other occupational studies have linked styrene exposure to hearing loss (138 mg/m^3 for 8.6 years) and decreased visuomotor accuracy (25 ppm for 4.9 years) (U.S. EPA 1994). Longer reaction times have been reported in several occupational studies with exposure concentrations ranging from 9 to >150 ppm and durations of days to years (U.S. EPA 1984).

2. Animals — Male rats exposed to 0, 800, 1000, or 1200 ppm styrene for 14 hours/day, 7 days/week for 3 weeks had increased auditory thresholds at 8-20 kHz in all treated groups (U.S. EPA 1994). Rabbits infused intravenously with a 10% solution of styrene at rates of 3.1-12.6 mg/minute, showed altered vestibular function observed as involuntary eye movements (U.S. EPA 1994). Several studies on the ototoxic effects of styrene are listed in TSCATS (1994), but no details were available.

V. ENVIRONMENTAL EFFECTS

Styrene is moderately toxic to aquatic organisms with toxicity values in the range of >1 mg/L to 100 mg/L. Styrene is expected to have low toxicity towards terrestrial animals. Styrene contributes to the formation of photochemical smog due to indirect photochemical reactions.

A. Toxicity to Aquatic Organisms

Ninety-six hour LC_{50} values for *Lepomis macrochirus* (bluegill), *Pimephales promelas* (fathead minnow), *Carassius auratus* (goldfish), and *Lebistes reticulatus* (guppy) are 25 mg/L, 46.4 mg/L (soft water), 64.74 mg/L, and 74.83 mg/L, respectively (U.S. EPA 1984). The 24- and 48-hour LC_{50}s for *Daphnia magna* (water flea) are 27 and 23 mg/L, respectively (U.S. EPA 1984).

B. Toxicity to Terrestrial Organisms

No information was found in the secondary sources searched regarding the toxicity of styrene to terrestrial organisms. However, based on the low acute toxicity of styrene to laboratory animals, it is unlikely that the chemical would cause adverse effects in terrestrial animals at levels normally found in the environment.

C. Abiotic Effects

Styrene reacts with ozone with an estimated half-life of 9 hours. The chemical is also a generator of photochemical smog due to indirect photochemical reactions (Howard 1989).

---

[2] For dose comparison purposes this has been calculated by multiplying 370 mg/m^3 by 0.024 (the 80 minute [1.33 hour] breathing rate, 1.66 m^3 [standard 8-hour breathing rate, 10 m^3], divided by the assumed adult body weight, 70 kg and assuming 100% absorption) to obtain the dose in mg/kg (U.S. EPA 1988b).

VI. EPA/OTHER FEDERAL/OTHER GROUP ACTIVITY

The Clean Air Act Amendments of 1990 list styrene as a hazardous air pollutant. Occupational exposure to styrene is regulated by the Occupational Safety and Health Administration (OSHA). The OSHA permissible exposure limit (PEL) is 100 parts per million parts of air (ppm) as an 8-hour time-weighted average (TWA) (29 CFR 1910.1000). In addition to OSHA, other federal agencies and groups may develop recommendations to assist in controlling workplace exposure. These agencies and groups (listed in Tables 6 and 7) should be contacted regarding workplace exposures and for additional information on styrene.

TABLE 6. EPA OFFICES AND CONTACT NUMBERS FOR INFORMATION ON STYRENE

EPA Office	Statute	Contact Number
Pollution Prevention & Toxics	PPA[a]	(202) 260-1023
	EPCRA (§313/TRI)[b]	(800) 535-0202
	TSCA (§8A)[c]	(800) 554-1404
Air	Clean Air Act (111, 112B)[d]	(919) 541-0888
Solid Waste & Emergency Response	RCRA[e] (Action levels: water, 7 mg/L; soil, 2E+4 mg/kg)	(800) 535-0202
	CERCLA[f] (RQ: 1000 pounds)	(800) 535-0202
Water	Safe Drinking Water Act[g] (MCL: 0.1 mg/L, MCLG: 0.1 mg/L, Health Advisories: 20 mg/L [ch/1d]; 2 mg/L [ch/10d]; 2 mg/L [ch/lt]; 7 mg/L [a/lt]; 0.1 mg/L [lifetime])	(800) 426-4791
	Clean Water Act (§311)[h]	(202) 260-7588

[a]**PPA**: Pollution Prevention Act

[b]**EPCRA**: Emergency Planning and Community Right to Know Act of 1986.

[c]**TSCA**: Toxic Substances Control Act

[d]Listed as hazardous air pollutant under §112 of Clean Air Act [42 U.S.C. 7401 et seq. (1990)].

[e]**RCRA**: Resource Conservation and Recovery Act [40 CFR §264.94 (1990)]. **Action Level**: Health and environmental-based levels used by the EPA as indicators for the protection of human health and the environment and as triggers for a Corrective Measure Study.

[f]**CERCLA**: Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended;

RQ: level of hazardous substance, which, if equaled or exceeded in a spill or release, necessitates the immediate reporting of that release to the National Response Center [40 CFR Part 302 (1991)].

[g]**MCL**: Maximum contaminant level [40 CFR Part 141 (1994)]; **MCLG**: Maximum contaminant level goal [40 CFR Part 141 (1994)]; **Health Advisories**: Estimated for a 10-kg child or a 70-kg adult consuming 2 L of water per day. **(ch/1d)**: Child, one-day health advisory = the concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects for up to 5 consecutive days of exposure, with a margin of safety; **(ch/10d)**: Child, ten-day health advisory = the concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects up to 14 consecutive days of exposure, with a margin of safety; **(ch/lt)**: Child, longer-term health advisory = the concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects up to approximately 7 yr (10% of an individual's lifetime) of exposure, with a margin of safety. **(a/lt)**: Adult, longer-term health advisory. **Lifetime**: lifetime health advisory, the concentration os a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects over a lifetime of exposure, with a margin of safety.

[h]Clean Water Act; regulates waters of the United States, including surface waters, ground waters, and wetlands [40 CFR Part 131 (1994)].

TABLE 7. OTHER FEDERAL OFFICES/CONTACT NUMBERS FOR INFORMATION ON STYRENE

Other Agency/Department/Group	Contact Number
American Conference of Governmental Industrial Hygienists (TLV-TWA: 50 ppm [213 mg/m^3] skin)[a]	(513) 742-2020
Agency of Toxic Substances & Disease Registry	(404) 639-6000
Consumer Product Safety Commission	(301) 504-0994
Food & Drug Administration	(301) 443-3170
National Institute for Occupational Safety & Health (TWA: 50 ppm [215 mg/m^3])[b]	(800) 356-4674
Occupational Safety & Health Administration (TWA[c]: 100 ppm [433 mg/m^3]; ceiling: 200 ppm; 600 ppm maximum peak for 5 minutes in any 5 hours	(Check local phone book under Department of Labor)

[a]**TLV-TWA**: Time-weighted-average concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be repeatedly exposed without adverse effects; skin = cutaneous absorption may occur and prevention of cutaneous absorption may be needed; air sampling alone is insufficient to accurately quantitate exposure.
[b]**TWA**: Time-weighted average concentration, usually for up to a 10-hour workday during a 40-hour workweek
[c]**TWA**: Time-weighted-average concentrations that must not be exceeded during any 8-hour workshift of a 40-hour workweek.

VII. CITED REFERENCES

ATSDR. 1992. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Styrene. U.S. Department of Health and Human Services, Public Health Service, Atlanta, GA, 140 pp.

Budavari S, O'Neil MJ, Smith A, Heckelman PE (Eds.). 1989. The Merck Index, 11th ed. Merck & Co., Inc., Rahway, NJ, p. 1397.

CHEMFATE. 1994. Syracuse Research Corporation's Environmental Fate Data Bases, retrieved 11/15/94. Syracuse Research Corporation, Syracuse, NY.

Chemical and Engineering News. 1994. Organics Led Last Year's Top 50 Chemicals Production Increase. April 11, 1994.

Grayson, M. (ed.). Kirk-Othmer Concise Encyclopedia of Chemical Technology, Third edition. New York: John Wiley and Sons, 1985.

Hansch and Leo. 1979.

Hazardous Substances Data Bank (HSDB), 1994.

Howard PH. 1989. Handbook of Environmental Fate and Exposure Data for Organic Chemicals. Vol. I Large Production and Priority Pollutants. Lewis Publishers, Chelsea, MI, pp.490-498.

IARC. 1979. International Agency for Research on Cancer. Monograph on Styrene, Polystyrene, and Styrene-Butadiene Copolymers. Volume 19: 231-274.

Keith LH and Walters DB (Eds.). 1987. Compendium of Safety Data Sheets for Research and Industrial Chemicals, Part VI; VCH Publishers, Deerfield Beach, pp. 3178-3179.

Mannsville Chemical Products Corporation. Styrene. Chemical Products Synopsis, July 1993.

NCI. 1979. National Cancer Institute. Bioassay of styrene for possible carcinogenicity. Technical Report Series No. 185, 44 pp.

Sax, N.I., and R.J. Lewis, Sr. (eds.). Hawley's Condensed Chemical Dictionary, Eleventh edition. New York: Van Nostrand Reinhold Company, 1987.

TRI92. 1994. 1992 Toxics Release Inventory Public Data Release. Office of Pollution Prevention and Toxics, U.S. EPA, Washington, D.C., p. 94.

TSCATS. 1994. MEDLARS Online Information Retrieval System. National Library of Medicine.

U.S. EPA. 1984. U.S. Environmental Protection Agency. Health and Environmental Effects Profile for Styrene. Office of Research and Development, U.S. EPA, Washington, D.C. ECAO-CIN-P103.

U.S. EPA. 1988a. U.S. Environmental Protection Agency. Health Effects Assessment for Styrene. Office of Research and Development, U.S. EPA, Washington, D.C. ECAO-CIN-H115.

U.S. EPA. 1988b. U.S. Environmental Protection Agency. Methodology for Evaluating Potential Carcinogenicity in Support of Reportable Quantity Adjustments Pursuant to CERCLA Section 102. Carcinogen Assessment Group, Office of Health and Environmental Assessment, U.S. EPA, Washington, D.C., pp. 21, 22. OHEA-C-073.

U.S. EPA 1994. U.S. Environmental Protection Agency. Integrated Risk Information System (IRIS) Online. Office of Health and Environmental Assessment, U.S. EPA, Cincinnati, OH.

USITC. 1994. United States International Trade Commission. Synthetic Organic Chemicals: United States Production and Sales, 1992, 76th edition. USITC Publication 2720, February 1994.

Verschueren K (Ed). 1983. Handbook of Environmental Data on Organic Chemicals, 2nd ed., Van Nostrand Reinhold Co., New York, pp. 1055-1057.

Windholz, M. (ed.). The Merck Index, Tenth edition. Rahway, N.J.: Merck and Company, Inc., 1983.

APPENDIX A. SOURCES SEARCHED FOR FACT SHEET PREPARATION

ACGIH. Most recent. American Conference for Governmental Industrial Hygienists, Inc. TLVs®. Documentation of the Threshold Limit Values and Biological Exposure Indices, ... ed. ACGIH, Cincinnati, OH.

AQUIRE. 1994. Aquatic Information Retrieval online data base. Chemical Information Systems, Inc., a subsidiary of Fein-Marquart Assoc.

ATSDR. 1989-1994. Agency for Toxic Substances and Disease Registry. Toxicological Profiles. Chamblee, GA: ATSDR.

Budavari S, O'Neil MJ, Smith A, Heckelman PE (Eds.). 1989. The Merck Index, 11th ed. Rahway, N.J.: Merck & Co., Inc.

Clayton GD, Clayton FE. 1981-1982. Patty's Industrial Hygiene and Toxicology, 3rd ed., Vol. 2C. New York: John Wiley & Sons. (Soon to be updated)

Clean Air Act. 1990. As amended. 42 U.S.C. 7412.

GENETOX. 1994. U.S. EPA GENETOX Program, computerized database.

Grayson, M. (ed.). Kirk-Othmer Concise Encyclopedia of Chemical Technology, Third edition. New York: John Wiley and Sons, 1985.

HSDB. 1994. Hazardous Substances Data Bank. MEDLARS Online Information Retrieval System, National Library of Medicine.

IARC. 1979-1994. International Agency for Research on Cancer. IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man. Lyon: IARC.

IPCS. 19.... International Programme on Chemical Safety. Environmental Health Criteria. World Health Organization, Geneva, Switzerland.

Mannsville Chemical Products Corporation. Styrene. Chemical Products Synopsis, July 1993.

NIOSH (National Institute for Occupational Safety and Health). 1992. NIOSH Recommendations for Occupational Safety and Health. Compendium of Policy Documents and Statements. Cincinnati, OH: NIOSH.

NTP. 199... National Toxicology Program. Toxicology and Carcinogenesis Studies. Tech Rep Ser.

NTP. 199... National Toxicology Program. Management Status Report. Produced from NTP Chemtrack system. April 8, 1994. National Toxicology Program, Research Triangle Park, NC.

OSHA. 1993. Occupational Safety and Health Administration. Table Z-2. Limits for Air Contaminants.

TSCATS. 199... MEDLARS Online Information Retrieval System, National Library of Medicine.

U.S. Air Force. 1989. The Installation Restoration Toxicology Guide, Vols. 1-5. Wright-Patterson Air Force Base, OH.

U.S. EPA . 1991. U.S. Environmental Protection Agency. Table 302.4 List of Hazardous Substances and Reportable Quantities 40 CFR, part 302.4:3-271.

U.S. EPA. U.S. Environmental Protection Agency. Appendix A. Examples of Concentrations Meeting Criteria for Action Levels. 40 CFR Part 264.521 (a)(2)(i-iv). Fed. Reg. 55:30865-30867.

U.S. EPA. Most current. Drinking Water Regulations and Health Advisories. Office of Drinking Water, U.S. Environmental Protection Agency, Washington, D.C.

U.S. EPA reviews such as Health and Environmental Effects Documents, Health and Environmental Effect Profiles, and Health and Environmental Assessments, HERD Analogue Profiles, ITC Documents.

U.S. EPA. 1994. Integrated Risk Information System (IRIS) Online. Cincinnati, OH: Office of Health and Environmental Assessment.

U.S. International Trade Commission (USITC). Synthetic Organic Chemicals: United States Production and Sales, 1992, 76th edition. USITC Publication 2720, February 1994.

Windholz, M. (ed.). The Merck Index, Tenth edition. Rahway, N.J.: Merck and Company, Inc., 1983.