



CHEMICAL UPDATE WORKSHEET

| | |
|-----------------------|---------------------|
| Chemical Name: | Styrene |
| CAS #: | 100-42-5 |
| Revised By: | RRD Toxicology Unit |
| Revision Date: | September 16, 2015 |

(A) Chemical-Physical Properties

| | Part 201 Value | Updated Value | Reference Source | Comments |
|--|----------------|---------------|------------------|----------|
| Molecular Weight (g/mol) | 104.15 | 104.15 | EPI | EXP |
| Physical State at ambient temp | Liquid | Liquid | MDEQ | |
| Melting Point (°C) | 243 | -31.00 | EPI | EXP |
| Boiling Point (°C) | 145 | 145.00 | EPI | EXP |
| Solubility (ug/L) | 3.10E+5 | 310000 | EPI | EXP |
| Vapor Pressure (mmHg at 25°C) | 6.232 | 6.40E+00 | EPI | EXP |
| HLC (atm-m³/mol at 25°C) | 2.75E-3 | 2.75E-03 | EPI | EXP |
| Log Kow (log P; octanol-water) | 2.94 | 2.95 | EPI | EXP |
| Koc (organic carbon; L/Kg) | 777 | 446.1 | EPI | EST |
| Ionizing Koc (L/kg) | | NR | NA | NA |
| Diffusivity in Air (Di; cm²/s) | 0.071 | 7.11E-02 | W9 | EST |
| Diffusivity in Water (Dw; cm²/s) | 8.0E-6 | 8.78E-06 | W9 | EST |
| Soil Water Partition Coefficient (Kd; inorganics) | NR | NR | NA | NA |

| | Part 201 Value | Updated Value | Reference Source | Comments |
|--|----------------|---------------|------------------|----------|
| Flash Point (°C) | 88 | 31 | CRC | EXP |
| Lower Explosivity Level (LEL; unitless) | 0.009 | 0.009 | CRC | EXP |
| Critical Temperature (K) | | 6.36E+02 | EPA2004 | EXP |
| Enthalpy of Vaporization (cal/mol) | | 8.74E+03 | EPA2004 | EXP |
| Density (g/mL, g/cm ³) | | 0.9016 | CRC | EXP |
| EMSOFT Flux Residential 2 m (mg/day/cm ²) | 2.17E-05 | 2.59E-05 | EMSOFT | EST |
| EMSOFT Flux Residential 5 m (mg/day/cm ²) | 3.68E-05 | 5.59E-05 | EMSOFT | EST |
| EMSOFT Flux Nonresidential 2 m (mg/day/cm ²) | 2.96E-05 | 4.05E-05 | EMSOFT | EST |
| EMSOFT Flux Nonresidential 5 m (mg/day/cm ²) | 4.64E-05 | 8.35E-05 | EMSOFT | EST |

(B) Toxicity Values/Benchmarks

| | Part 201 Value | Updated Value | Source/Reference/ Date | Comments/Notes /Issues |
|---|--|--|---------------------------|---------------------------|
| Reference Dose (RfD) (mg/kg/day) | 2.0E-1 | 2.0E-1 | IRIS, 1990 | |
| RfD details | Dog sub chronic oral study. NOAEL = 200 mg/kg; LOAEL = 400 mg/kg; Critical effects = red blood cell and liver effects (Quast et al., 1979). UF = 1000. CCD/RRD date: 10/9/85 | <p>Tier 1 Source: IRIS: Basis: IRIS is a Tier 1 source. IRIS RfD = 2.0E-1 mg/kg-day. Critical Study: Quast, J.F., C.G. Humiston, R.Y. Kalnins, et al. 1979. Results of a toxicity study of monomeric styrene administered to beagle dogs by oral intubation for 19 months. Toxicology Research Laboratory, Health and Environmental Sciences, DOW Chemical Co., Midland, MI. Final Report. Method(s): Four beagle dogs/sex were gavaged with doses of 0, 200, 400, or 600 mg styrene/kg bw/day in peanut oil for 560 days. Critical effect: red blood cell and liver effects End point or Point of Departure (POD): NOAEL = 200 mg/kg-day Uncertainty Factors: UF = 1,000 (10 each for intraspecies variability, interspecies extrapolation and use of a sub chronic study). Source and date: IRIS, Last revision date – 9/01/1990. The IRIS file noted that “RfD for styrene may change in the near future pending the outcome of a review” being conducted by an EPA Work Group. Per IRIS Track (3/3/1/2015), the styrene assessment is in draft development stage and completion date is “TBD”.</p> <p>Tier 2 Sources: PPRTV: No PPRTV record available at this time. MRL: Per ATSDR (11/2010), no chronic or intermediate oral MRL is available at this time. An acute oral MRL = 1.0E-1 mg/kg-day is presented and derived as follows: Critical Study: Husain R, Srivastava SP, Seth PK. 1985. Some behavioral effects of early styrene intoxication in experimental animals. Arch Toxicol 57:53-55. Method(s): Groups of 15 male Wistar rats were administered by gavage 0, 100, or 200 mg/kg/day styrene in ground nut oil for 14 consecutive days. Spontaneous motor activity for a period of 10 minutes was measured 24 hours after the last</p> | IRIS, 1990 | Complete |

| | Part 201 Value | Updated Value | Source/Reference/Date | Comments/Notes/Issues |
|--|---|--|-----------------------|-----------------------|
| | | dose. Critical effect: increases in percent avoidance response (indicative of impaired learning) End point or Point of Departure (POD): LOAEL = 100 mg/kg-day Uncertainty Factors: UF = 1,000 (10 each for intraspecies variability, interspecies extrapolation and use of a LOAEL). Tier 3 Source: MDEQ: Per DEQ-CCD, RRD (10/9/1985) adopted the IRIS RfD. Per CCD, WRD (9/021998), presents an RfD = 2.0E-1 mg/kg-day similar to the IRIS RfD and using the same critical study (Quast et. al., 1979) and UF values. | | |
| Oral Cancer Slope Factor (CSF) (mg/kg-day)⁻¹ | 1.3E-2 | 1.3E-2 | MDEQ, 2000 | |
| CSF details | Lung carcinomas/adenomas in male B6C3F1 following treatment by gavage, 5 days/week for 78 weeks followed by a 13 week observation period (NCI, 1979). Revised species scaling factor of (BWh/BWa) to the 0.25 power used for q* calculation. CCD/RRD date: 1/18/2000. | Tier 3 Source: MDEQ: Basis: MDEQ is the only value from the Tier 3 search. See details below. Carcinogen Weight-of-Evidence (WOE) Class: “reasonably anticipated to be a human carcinogen” WOE Basis: based on human cancer studies, laboratory animal studies, and supporting mechanistic data. Source and Date: ATSDR Addendum to the Toxicological Profile (Update) for Styrene, 9/2011; National Toxicology Program (NTP) 13 th Report on Carcinogens (6/10/2011) Tier 1 and 2 Sources: IRIS: Per IRIS (7/01/1993), no value at this time. IRIS has not evaluated the carcinogenic potential of styrene. PPRTV: No PPRTV record available at this time. MRL: NA; MRLs are for non-cancer effects only. Tier 3 Sources: | | Complete |



| | Part 201 Value | Updated Value | Source/Reference/ Date | Comments/Notes /Issues |
|--|---|---|---------------------------|---------------------------|
| | | <p>MDEQ: Critical Study: NCI, 1979 NCI. 1979a. Bioassay of a solution of β-nitrostyrene and styrene for possible carcinogenicity. Bethesda, MD: National Cancer Institute, Division of Cancer Cause and Prevention. DHEW Publication No. (NIH) 79-1726. NCI. 1979b. Bioassay of styrene for possible carcinogenicity. Bethesda, MD: National Cancer Institute, Division of Cancer Cause and Prevention. Technical Report Series No. 185. NCI-CG-TR-185. NIH 79-1741. PB300977. Method(s): B6C3F1 rats (/sex/group) were exposed to _____ by gavage, 5 days/week for 78 weeks followed by a 13 week observation period. 1) <i>Dose response data: Tumor Type</i> – lung carcinomas/adenomas; <i>Test Species</i> – rats, male; <i>Route</i> - oral (gavage) 2) <i>Extrapolation method:</i> Linear approach Source and Date: MDEQ-CCD/RRD, 1/18/2000</p> <p>Other Tier 3: No value is available at this time from these Tier 3 sources/databases: HEAST, NTP ROC, health and environmental agencies of California, Massachusetts, Minnesota, New Jersey, New York, and Texas, WHO (IARC), WHO (IPCS/INCHEM), Canada, The Netherlands (RIVM), ECHA (REACH) and OECD HPV.</p> | | |
| Reference Concentration (RfC) or Initial Threshold Screening Level (ITSL) ($\mu\text{g}/\text{m}^3$) | 1.0E+3 | 9.0E+2 | ATSDR, 2010 | |
| RfC/ITSL details | No AQD details provided in CCD (9/19/2011). | <p>Tier 2 Source: ATSDR: Basis: ATSDR is more current than IRIS and based on a more recent study and assessment. ATSDR inhalation chronic MRL = 0.2 ppm ($0.9 \text{ mg}/\text{m}^3$) based on occupational exposures. Critical Study: Benignus VA, Geller AM, Boyes WK, et al. 2005. Human</p> | | Complete |

| | Part 201 Value | Updated Value | Source/Reference/ Date | Comments/Notes /Issues |
|--|----------------|---|---------------------------|---------------------------|
| | | <p>neurobehavioral effects of long-term exposure to styrene: a meta-analysis. Environ Health Perspect 113:532-538.</p> <p>Method(s): Meta-analysis used data from occupational exposure studies examining color vision impairment (Campagna et al. 1996; Eguchi et al. 1995; Gobba et al. 1991; Gong et al. 2002; Kishi et al. 2001) and delays in choice reaction time (Jegaden et al. 1993; Mutti et al. 1984a; Triebig et al. 1989; Tsai and Chen 1996). Average styrene exposure concentrations for each study were estimated from individual data reported in the papers; for studies reporting individual data as urinary mandelic acid levels, standardized methods for converting to styrene exposure levels were used. Cumulative styrene exposure was estimated by multiplying exposure level by length of employment. A common metric of effect magnitude (percentage of baseline) was calculated for the different neurological effects.</p> <p>Critical effect: neurological effects (increase in choice reaction time and increase in CCI score for color discrimination)</p> <p>End point or Point of Departure (POD): LOAEL = 20 ppm; LOAEL_{ADJ} = 20 ppm x 8 hours/24 hours x 5 days/7 days = 4.8 ppm</p> <p>Uncertainty Factors: 30 (10 for intraspecies variability and 3 for use of a minimal LOAEL)</p> <p>Source and date: ATSDR, 11/2010</p> <p>Tier 1 and 2 Sources:</p> <p>IRIS: IRIS (1993) RfC = 1.0 mg/m³ = 1,000 ug/m³</p> <p>Critical Study: Mutti, A., A. Mazzucchi, P. Rusticelli, G. Frigeri, G. Arfini, and I. Franchini. 1984. Exposure-effect and exposure-response relationships between occupational exposure to styrene and neuropsychological functions. Am. J. Ind. Med. 5: 275-286.</p> <p>Method(s): An occupational study: the neuro-psychological function of 50 workers exposed to styrene for a mean duration of 8.6 (SD of 4.5) years was evaluated. Styrene exposure, as assessed by the authors, corresponded to air concentrations ranging from 10-300 ppm as a mean daily exposure. These concentrations were estimated from the summation of the principal urinary</p> | | |

| | Part 201 Value | Updated Value | Source/Reference/Date | Comments/Notes/Issues |
|---|---|--|-----------------------|-----------------------|
| | | <p>metabolites of styrene, mandelic acid (MA) and phenylglyoxylic acid (PGA). Urinary metabolite levels are considered as reliable biological indicators of styrene exposure (ACGIH, 1986; WHO, 1983).</p> <p>Critical effect: CNS (intellectual function, memory and reaction times (visuo-motor speed)) effects.</p> <p>End point or Point of Departure (POD): NOAEL = 94 mg/m³ (25 ppm = 150 mmole urinary styrene adjusted to lower 95% confidence limit = 22 ppm); NOAEL_{HEC} = 34 mg/m³</p> <p>Uncertainty Factors: UF = 30 (10 for intraspecies variability and 3 for database inadequacy)</p> <p>Source and date: IRIS, Last revision date – 7/01/1993</p> <p>PPRTV: No PPRTV record available at this time.</p> <p>Tier 3 Source: MDEQ: Per DEQ-CCD (5/12/2014), AQD adopted the IRIS RfC value of 1,000 ug/m³.</p> | | |
| Inhalation Unit Risk Factor (IURF) ((µg/m³)⁻¹) | 5.7E-7 | 5.7E-7 | MDEQ, 2014 | |
| IURF details | Based on Jersey et al (1978) female rat leukemia and lymphosarcoma incidence, as reported in EPA's 1988 Drinking Water Criteria Document. Potency was converted from EPA's oral slope factor of 2.0E-3 (mg/kg)-1. | <p>Tier 3 Source: MDEQ: Basis: No other Tier 3 values are available. MDEQ value based on Jersey et al (1978) study. See details below.</p> <p>Carcinogen Weight-of-Evidence (WOE) Class: "Reasonably anticipated to be a human carcinogen"</p> <p>WOE Basis: based on human cancer studies, laboratory animal studies, and supporting mechanistic data.</p> <p>Source and Date: MDEQ-CCD/AQD, 11/5/1992; National Toxicology Program (NTP) 13th Report on Carcinogens (6/10/2011)</p> <p>Tier 1 and 2 Sources: IRIS: Per IRIS (7/01/1993), no value at this time. IRIS has not evaluated the</p> | | Complete |



| | Part 201 Value | Updated Value | Source/Reference/ Date | Comments/Notes /Issues |
|--|-----------------------------|---|---------------------------|---------------------------|
| | CCD/AQD date: 11/5/1992. | <p>carcinogenic potential of styrene. PPRTV: No PPRTV record available at this time. MRL: NA; MRLs are for non-cancer effects only.</p> <p>Tier 3 Sources: MDEQ: MDEQ/AQD (5/12/2014) ITSL = $5.7E-7$ ($\mu\text{g}/\text{m}^3$)⁻¹. Based on Jersey et al (1978) female rat leukemia and lymphosarcoma incidence, as reported in EPA's 1988 Drinking Water Criteria Document. Potency was converted from EPA's oral slope factor of $2E-3$ (mg/kg)⁻¹. Critical Study: Jersey, G.C., M.F. Balmer, J.F. Quast et al. 1978. Two-year chronic inhalation toxicity and carcinogenicity study on monomeric styrene in rats. Dow Chemical Study for the Chemical Manufacturing Association, December 6, 1978. Method(s): 1) <i>Dose response data: Tumor Type</i> - leukemia and lymphosarcoma; <i>Test Species</i> – rat, female; <i>Route</i> - inhalation 2) <i>Extrapolation method:</i> Source: MDEQ/AQD (Calculation date: 5/12/2014; CAS date: 10/1/2012)</p> <p>New Jersey DEP: IURF= $5.7E-07$ ($\mu\text{g}/\text{m}^3$)⁻¹ based on HEAST 91. The HEAST 1997 edition does not present an IURF value.</p> <p>Other Tier 3: No value is available at this time from these Tier 3 sources/databases: HEAST, NTP ROC, health and environmental agencies of California, Massachusetts, Minnesota, New York, and Texas, WHO (IARC), WHO (IPCS/INCHEM), The Netherlands (RIVM), Canada, ECHA (REACH) and OECD HPV.</p> | | |
| Mutagenic Mode of Action (MMOA)? (Y/N) | -- | NO | USEPA, 2015 | |
| MMOA Details | -- | NA Not listed as a carcinogen with mutagenic MOA in the USEPA OSWER List. | | |
| Developmental or Reproductive Effector? (Y/N) | No | No, the RfD is not based on a reproductive-developmental effect. Acute oral MRL is based on critical effects that include | MDEQ, 2015 | |

| | Part 201 Value | Updated Value | Source/Reference/ Date | Comments/Notes /Issues |
|--|----------------|---|--------------------------------|---------------------------|
| | | impaired learning. See above. | | |
| Developmental or Reproductive Toxicity Details | NA | NA | | |
| State Drinking Water Standard (SDWS) (ug/L) | -- | 100 | SDWA, 1976 | |
| SDWS details | NA | MI Safe Drinking Water Act (SDWA) 1976 PA 399 | | |
| Secondary Maximum Contaminant Level (SMCL) (ug/L) | -- | NO | SDWA, 1976 and USEPA SMCL List | |
| SMCL details | NA | MI Safe Drinking Water Act (SDWA) 1976 PA 399 and USEPA SMCL List, 2015 | | |
| Is there an aesthetic value for drinking water? (Y/N) | NO | Not evaluated. | NA | |
| Aesthetic value (ug/L) | NA | NA | NA | |
| Aesthetic Value details | NA | NA | | |
| Phytotoxicity Value? (Y/N) | NO | Not evaluated. | NA | |
| Phytotoxicity details | NA | NA | NA | |
| Others | | | | |

(C) Chemical-specific Absorption Factors

| | Part 201 Value | Update | Source/Reference/ Dates | Comments/Notes /Issues |
|---|----------------|------------------------------------|-------------------------------|---------------------------|
| Gastrointestinal absorption efficiency value (ABS _{gi}) | --- | 1.0 | MDEQ, 2015/USEPA RAGS-E, 2004 | |
| ABS _{gi} details | | RAGS E (USEPA, 2004) Default Value | | |
| Skin absorption efficiency value (AE _d) | --- | 0.1 | MDEQ, 2015 | |
| AE _d details | | | | |
| Ingestion Absorption Efficiency (AE _i) | | 1.0 | MDEQ, 2015 | |
| AE _i Details | | | | |
| Relative Source Contribution for Water (RSC _w) | | 0.2 | MDEQ, 2015 | |
| Relative Source Contribution for Soil (RSC _s) | | 1.0 | MDEQ, 2015 | |
| Relative Source Contribution for Air (RSC _A) | | 1.0 | MDEQ, 2015 | |
| Others | | | | |

(D) Rule 57 Water Quality Values and GSI Criteria

| | |
|--|--------|
| Current GSI value (µg/L) | 80 (X) |
| Updated GSI value (µg/L) | 80 (X) |
| Rule 57 Drinking Water Value (µg/L) | 20 |

| | Rule 57 Value (µg/L) | Verification Date |
|--|---------------------------------|--------------------------|
| Human Non-cancer Values- Drinking water source (HNV-drink) | 4,200 | 9/1998 |
| Human Non-Cancer Values- Non-drinking water sources (HNV-Non-drink) | 18,000 | 9/1998 |
| Wildlife Value (WV) | NA | NA |
| Human Cancer Values for Drinking Water Source (HCV-drink) | 20 | 9/1998 |
| Human Cancer values for non-drinking water source (HCV-Non-drink) | 80 | 9/1998 |
| Final Chronic Value (FCV) | 160 | 2/1998 |
| Aquatic maximum value (AMV) | 1,400 | 2/1998 |
| Final Acute Value (FAV) | 2,900 | 2/1998 |

Sources:

1. MDEQ Surface Water Assessment Section Rule 57 [website](#)
2. MDEQ Rule 57 [table](#)

(E) Target Detection Limits (TDL)

| | Value | Source |
|---|--------------|---------------|
| Target Detection Limit – Soil ($\mu\text{g}/\text{kg}$) | 50 | MDEQ, 2015 |
| Target Detection Limit – Water ($\mu\text{g}/\text{L}$) | 1 | MDEQ, 2015 |
| Target Detection Limit – Air (ppbv) | 1.10E+01 | MDEQ, 2015 |
| Target Detection Limit – Soil Gas (ppbv) | 3.50E+02 | MDEQ, 2015 |

CHEMICAL UPDATE WORKSHEET ABBREVIATIONS:

CAS # - Chemical Abstract Service Number.

Section (A) Chemical-Physical Properties**Reference Source(s):**

| | |
|-----------|---|
| CRC | Chemical Rubber Company Handbook of Chemistry and Physics, 95th edition, 2014-2015 |
| EMSOFT | USEPA Exposure Model for Soil-Organic Fate and Transport (EMSOFT) (EPA, 2002) |
| EPA2001 | USEPA (2001) Fact Sheet, Correcting the Henry's Law Constant for Soil Temperature. Office of Solid Waste and Emergency Response, Washington, D.C. |
| EPA4 | USEPA (2004) User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings. February 22, 2004. |
| EPI | USEPA's Estimation Programs Interface SUITE 4.1, Copyright 2000-2012 |
| HSDB | Hazardous Substances Data Bank |
| MDEQ | Michigan Department of Environmental Quality |
| NPG | National Institute for Occupational Safety and Health Pocket Guide to Chemical Hazards |
| PC | National Center for Biotechnology Information's PubChem database |
| PP | Syracuse Research Corporation's PhysProp database |
| SCDM | USEPA's Superfund Chemical Data Matrix |
| SSG | USEPA's Soil Screening Guidance: Technical Background Document, Second Edition, 1996 |
| USEPA/EPA | United States environmental protection agency's Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). July, 2004. |

W9 USEPA's User Guide for Water9 Software, Version 2.0.0, 2001

Basis/Comments:

| | |
|-----|---------------------------------|
| EST | estimated |
| EXP | experimental |
| EXT | extrapolated |
| NA | not available or not applicable |
| NR | not relevant |

Section (B) Toxicity Values/Benchmarks**Sources/References:**

| | |
|-------------|--|
| ATSDR | Agency for Toxic Substances and Disease Registry |
| CALEPA | California Environmental Protection Agency |
| CAL DTSC | California Department of Toxic Substances Control |
| CAL OEHHHA | CAEPA Office of Environmental Health Hazard Assessment |
| CCD | MDEQ Chemical Criteria Database |
| ECHA | European Chemicals Agency (REACH) |
| OECD HPV | Organization for Economic Cooperation and Development HPV Database |
| HEAST | USEPA's Health Effects Assessment Summary Tables |
| IRIS | USEPA's Integrated Risk Information System |
| MADEP | Massachusetts Department of Environmental Protection |
| MDEQ/DEQ | Michigan Department of Environmental Quality |
| DEQ-CCD/AQD | MDEQ Air Quality Division |
| DEQ-CCD/RRD | MDEQ Remediation and Redevelopment Division |
| DEQ-CCD/WRD | MDEQ Water Resources Division |
| MNDOH | Minnesota Department of Health |

| | |
|-------------|---|
| NJDEP | New Jersey Department of Environmental Protection |
| NYDEC | New York State Department of Environmental Conservation |
| OPP/OPPT | USEPA's Office of Pesticide Programs |
| PPRTV | USEPA's Provisional Peer Reviewed Toxicity Values |
| RIVM | The Netherlands National Institute of Public Health and the Environment |
| TCEQ | Texas Commission on Environmental Quality |
| USEPA | United States Environmental Protection Agency |
| USEPA OSWER | USEPA Office of Solid Waste and Emergency Response |
| USEPA MCL | USEPA Maximum Contaminant Level |
| WHO | World Health Organization |
| WHO IPCS | International Programme on Chemical Safety (IPCS/INCHEM) |
| WHO IARC | International Agency for Research on Cancers |
| NA | Not Available. |
| NR | Not Relevant. |

Toxicity terms:

| | |
|-------------|---|
| BMC | Benchmark concentration |
| BMCL | Lower bound confidence limit on the BMC |
| BMD | benchmark dose |
| BMDL | Lower bound confidence limit on the BMD |
| CSF | Cancer slope Factor |
| CNS | Central nervous system |
| IURF or IUR | Inhalation unit risk factor |
| LOAEL | Lowest observed adverse effect level |
| LOEL | Lowest observed effect level |
| MRL | Minimal risk level (ATSDR) |
| NOAEL | No observed adverse effect level |
| NOEL | No observed effect level |

| | |
|-------|-------------------------|
| RfC | Reference concentration |
| RfD | Reference dose |
| p-RfD | Provisional RfD |
| aRfD | Acute RfD |
| UF | Uncertainty factor |
| WOE | Weight of evidence |

Section (C) Chemical-specific Absorption Factors

| | |
|--------------|---|
| MDEQ | Michigan Department of Environmental Quality |
| USEPA RAGS-E | United States Environmental Protection Agency's Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). July, 2004. |

Section (D) Rule 57 Water Quality Values and GSI Criteria

| | |
|-----|---|
| GSI | Groundwater-surface water interface |
| NA | A value is not available or not applicable. |
| ID | Insufficient data to derive value |
| NLS | No literature search has been conducted |