STYRENE, MONOMER

CAS number: 100-42-5

Synonyms: Cinnamene, ethenyldenzene, ethylbenzol, phenylethylene, vinylbenzene

Chemical formula: C_8H_8

Structural formula: —

Workplace exposure standard (amended)

TWA: **20 ppm (85 mg/m^3)**

STEL: **40 ppm (170 mg/m^3)**

Peak limitation: **—**

Notations: **—**

IDLH: **700 ppm**

Sampling and analysis: The recommended value is quantifiable through available sampling and analysis techniques.

Recommendation and basis for workplace exposure standard

A TWA of 20 ppm (85 mg/m^3) is recommended to protect for effects to the central and peripheral nervous systems and irritation to the mucous membrane and upper respiratory tract in exposed workers.

A STEL of 40 ppm (170 mg/m^3) is recommended to protect for acute effects on the central and peripheral nervous system and mucous membrane and upper respiratory tract irritation in exposed workers.

Discussion and conclusions

Styrene is used in the manufacture of polystyrene plastics, protective coatings, styrenated polyesters, copolymer resins with acrylonitrile and butadiene and as a chemical intermediate. It has also been used in paints, sealers and other surface coatings.

Critical effects of exposure are on the central and peripheral nervous system and also irritation of the mucous membrane and upper respiratory tract.

Indications of central and peripheral neurologic, optic and irritant actions are reported in humans exposed at the workplace at airborne concentrations greater than 50 ppm. Headache, fatigue, nausea and dizziness are reported after exposure at concentrations greater than 100 ppm (ACGIH, 2018). Simple reaction times are increased, and coordination is decreased in controlled studies of volunteers inhaling 50 ppm for one hour and 380 ppm for 30 minutes. Increased reaction times are observed in 106 workers exposed at 13 to 101 ppm compared to other groups of workers not exposed to styrene. Reduced attention and reduced manual dexterity are reported among styrene workers exposed at TWA of 72 to 168 ppm (ACGIH, 2018). A significant decrease in colour vision perception among workers exposed is reported at concentration greater than 50 ppm compared to controls. Colour vision deficiencies are reported as being transient. Clinical and workplace evaluations of 900

employees found a threshold for ocular and conjunctival irritation at 50 ppm with another study in humans noting obvious ocular and upper respiratory tract irritation occurring at concentrations greater than 200 ppm (ACGIH, 2018). No histological alterations are observed in nasal biopsies from styrene workers exposed at 50 to 60 ppm for seven years (NICNAS, 2013). It is reported as an irritant in the upper respiratory tract of rodents at concentrations as low as 50 ppm (ACGIH, 2018).

Based on the weight of evidence indicating adverse effects starting at 50 ppm, the TWA of 20 ppm derived by ACGIH is recommended to protect for central and peripheral nervous system effects and for irritation effects.

The evidence from short-term effects as low as 50 ppm in humans warrants a STEL of 40 ppm as derived by ACGIH.

Recommendation for notations

Not classified as a carcinogen according to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS).

Not classified as a skin sensitiser or respiratory sensitiser according to the GHS.

A skin notation is not recommended based on the available evidence.

APPENDIX

Primary sources with reports

Source	Year set	Standard
SWA	***1991***	***TWA: 50 ppm (213 mg/m^3); STEL: 100 ppm (426 mg/m^3)***
Adopted from ACGIH.		
ACGIH	***2001***	***TLV-TWA: 20 ppm (85 mg/m^3); TLV-STEL: 40 ppm (170 mg/m^3)***

Recommended TLV-TWA and TLV-STEL are intended to minimise the potential for CNS and PNS effects and for mucous membrane and respiratory irritation.

Summary of data:

Basis of TWA and STEL:

- Clear indications of central and peripheral neurologic, optic and irritant actions in humans >50 ppm in the workplace
- Headache, fatigue, nausea and dizziness consistently reported post 100 ppm exposure
- Evidence concerning influence of occupational styrene exposure on sensory nerve conduction included
- 5–10% reductions in sensory nerve conduction after exposure at ≥100 ppm, no further information; reduced peripheral nerve conduction velocity and sensory amplitude after exposure at 50–100 ppm; slowed reaction time appears to begin at >50 ppm; significant loss of colour discrimination
- Colour vision deficiencies transient with improvement occurring 1 mo to 2 yr after reductions in exposure; no further information
- Not clear if changes in visual acuity or peripheral nerve conduction velocity and slowed reaction time relate to average exposures or high, peak exposures (215–469 ppm)
- ATSDR (1992) calculated an oral "minimal risk level" for styrene exposure of 2 mg/kg/d
- Mucous membrane irritation reported to begin at 45 ppm to as high as 180 ppm in humans. No further information
- Clearly irritant in upper respiratory tract at concentrations as low as 50 ppm in rodents.

Human data:

- Epidemiologic data considered inadequate to determine possible contribution of styrene exposure to human cancer
- Clinical and workplace evaluations of 900 employees found threshold for ocular and conjunctival irritation at 50 ppm. No evidence for hepatic or haematologic abnormalities after chronic exposure at 5–200 ppm
- No increase in chemical-specific mortality among 560 adult males employed in styrene operations at 1–20 ppm for at least 5 yr; similar findings in other study; no further details
- No significant increase in total or cause-specific mortality among workers in styrene-butadiene plants with up to 33 yr of mean styrene concentration of 2 ppm with peak concentrations of about 12 ppm
- No specific associations between reproductive failure or excess risk of adverse pregnancy outcome and occupational exposure
- Simple reaction times increased, and coordination decreased in controlled studies of volunteers exposed to:
  - 350 ppm (*via* mouth tube) for 30 min
  - 380 ppm for 1 h
  - 200 ppm for 1.5 h
  - 150 ppm for 1.5 h
  - 50 ppm for 1 h
- Controlled inhalation with 300 ppm (*via* mouth tube) for 1 h reduced ocular tracking abilities in all five volunteers but no changes in balance or coordination were noted

Source	Year set	Standard

- Increased reaction times compared to other groups of workers not exposed to styrene identified from a summary of different studies:
  - 106 employees with exposures of 13–101 ppm
  - 17 employees with exposures of 150 ppm
  - 27 employees with mean exposures of 92 ppm (range = 52–117 ppm)
  - 7 workers with mean exposures of 10 ppm
  - 10 employees with elevated urinary mandelic acid concentrations (approximating workplace air styrene at 65–110 ppm)
- Reaction times of workers exposed at TWA ≤235 ppm (with brief exposures at 1,500 ppm) increased compared with those exposed at TWA ≤139 ppm; no further information
- Reduced attention and manual dexterity among styrene workers exposed at TWA of 72–168 ppm, no further details
- Marginal improvements in worker reaction time for 17 men after mean workplace air concentrations reduced from 92–23 ppm, no further details
- Frank ocular and upper respiratory tract irritation at concentrations >200 ppm
- 10 males and 8 females exposed for 7.5 h/d, 3–4 d/w for 4 w at 20–125 ppm of which only 4 men and 2 women completed the protocol:
  - no changes in EEG in 3 people
  - the other 3 peoples complained of headache and dizziness at ≥75 ppm and nausea after inhaling ≥100 ppm (changes interpreted as reflecting boredom)
- A significant decrease in colour vision acuity principally affecting blue-yellow range compared with controls was reported in workers exposed at TWA >50 ppm,
- Significant reductions in colour discrimination observed in 36 styrene workers exposed at 15 ppm compared to the 36 controls
- Variable (2–8%) reductions in worker peripheral nerve conduction velocities; no further information
- Dermal penetration rate of 1±0.5 µg/cm^2/h reported (hand dipped in styrene) however another study (considered compromised by evaporation) indicated (9–15 mg/cm^2/h).

Animal data:

- A 50% reduction in respiratory rate occurred in mice that inhaled 160 ppm for 3 min
- No ototoxicity identified in rats exposed at 50 or 200 ppm, 6 h/d for 13 wk
- Rats exposed for 6 h/d, 5 d/wk for their lifetimes at 50, 200, 500 or 1000 ppm:
  - reduced body weight gain and decreased food consumption at 500 and 1000 ppm exposures, respectively:
  - no treatment-related increase in numbers of animals with tumours or numbers of tumours per animal observed when compared to concurrent controls
  - atrophy and degeneration of the olfactory epithelium (dorsal septum, dorsal meatus, medial nasal turbinates, ethmoid/dorsal turbinates) at all styrene concentrations examined
  - no NOAEL could be identified.

Insufficient data to recommend a Skin or sensory notation.

DFG	***1987***	***MAK: 20 ppm (86 mg/m^3)***

Summary of additional data:

- Metabolises to styrene-7,8-oxide, a direct alkylating agent
- In 4 studies with mice, styrene induced lung tumours, both after oral administration and following inhalation exposure; in 9 studies with rats was not carcinogenic; no further details
- Given this information, considered genotoxic and with carcinogenic potential to humans, however, the risk for humans may be evaluated
- The risk of developing cancer during a lifetime as a result of 40 yr occupational exposure to a concentration of styrene in air of 20 ppm is smaller than the unavoidable risk caused by

Source	Year set	Standard
	endogenous ethylene oxide, for which a value of ~1/10,000 has been estimated; no further information.	
SCOEL	***NA***	***NA***
No report.		
OARS/AIHA	***NA***	***NA***
No report.		
HCOTN	***NA***	***NA***
No report.		

Secondary source reports relied upon

Source		Year	Additional information
NICNAS	✓	2013	• Acute inhalation in humans is associated with eye/skin/throat irritation and neurological findings at high concentrations; NOAEC (men, inhalation) of 216 ppm (1 h) and 99 ppm (7 h) reported; no further information • No histological alterations observed in nasal biopsies from styrene workers exposed to 50–60 ppm for 7 yr; no further information • A 10 yr mortality score determined using 6678 male rubber-factory workers which were exposed to the chemical. Results showed elevated incidence of haemopoietic and lymphatic cancer: o incidence of cancer increased with years of exposure o the incidence in workers with a 2-yr history and 5 yr history was 4.4 and 5.6 times higher, respectively, than the general population • Based on *in vivo* no convincing evidence of significant mutagenic potential • The results from *in vitro* assays (including the Ames test and *in vitro* chromosome aberration studies in mammalian cells) suggest the chemical possesses some genotoxic potential *in vitro.* Metabolic activation is required for this activity.

Carcinogenicity — non-threshold based genotoxic carcinogens

Is the chemical mutagenic?	Insufficient data
Is the chemical carcinogenic with a mutagenic mechanism of action?	No

The chemical is not a non-threshold based genotoxic carcinogen.

Notations

Source	Notations
SWA	—

Source	Notations
HCIS	—
NICNAS	Carc. Cat 3
EU Annex	NA
ECHA	—
ACGIH	Carcinogenicity – A4
DFG	Carcinogenicity – 5
SCOEL	NA
HCOTN	—
IARC	Carcinogenicity – Group 2A
US NIOSH	NA

NA = not applicable (a recommendation has not been made by this Agency); — = the Agency has assessed available data for this chemical but has not recommended any notations

Skin notation assessment

Calculation	
Adverse effects in human case study:	no
Dermal LD_{50} ≤1000 mg/kg:	
Dermal repeat-dose NOAEL ≤200 mg/kg:	
Dermal LD_{50}/Inhalation LD_{50} <10:	
In vivo dermal absorption rate >10%:	
Estimated dermal exposure at WES >10%:	no
	a skin notation is not warranted

IDLH

Is there a suitable IDLH value available? Yes

Additional information

Molecular weight:	104.15
Conversion factors at 25°C and 101.3 kPa:	1 ppm = 4.26 mg/m^3; 1 mg/m^3 = 0.23 ppm
This chemical is used as a pesticide:	☐
This chemical is a biological product:	☐
This chemical is a by-product of a process:	☐

Molecular weight:	104.15
Conversion factors at 25°C and 101.3 kPa:	1 ppm = 4.26 mg/m^3; 1 mg/m^3 = 0.23 ppm
This chemical is used as a pesticide:	☐
A biological exposure index has been recommended by these agencies:	✓ ACGIH ✓ DFG ☐ SCOEL

Workplace exposure standard history

Year	Standard
Click here to enter year	

References

American Conference of Industrial Hygienists (ACGIH®) (2018) TLVs® and BEIs® with 7th Edition Documentation, CD-ROM, Single User Version. Copyright 2018. Reprinted with permission. See the *TLVs® and BEIs® Guidelines section* on the ACGIH website.

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Health Council of the Netherlands (HCOTN) (2001) Styrene. Health-based calculated occupational cancer risk values. The Hague: Health Council of the Netherlands; publication no. 2001/08OSH.

International Agency for Research on Cancer (IARC) (In prep.) Styrene. IARC Monographs on the evaluation of the carcinogenic risk to humans.

National Industrial Chemicals Notification and Assessment Scheme (NICNAS) (2013) Benzene, ethenyl: Human health tier II assessment – IMAP report.

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