# SULFUR DIOXIDE

**CAS number:** 7446-09-5

**Synonyms:** Sulfurous acid anhydride, sulphurous anhydride, sulphur dioxide, sulfurous oxide, sulfur superoxide

**Chemical formula:** $SO_2$

## Workplace exposure standard (amended)

**TWA:** —

**STEL:** **0.25 ppm (0.65 mg/m$^3$)**

**Peak limitation:** —

**Notations:** —

**IDLH:** **100 ppm**

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

## Recommendation and basis for workplace exposure standard

A STEL of 0.25 ppm (0.65 mg/m$^3$) is recommended to protect for acute irritant effects in exposed workers, including those with respiratory conditions.

## Discussion and conclusions

Sulfur dioxide ($SO_2$) is commonly produced in large quantities in major manufacturing industries and frequently released in paper and pulp, metal manufacturing and oil refining. It is also released in food, agriculture and wastewater treatment processes.

The critical effects of exposure are irritation of the respiratory tract and reduced lung function with the potential for reduction in pulmonary function in individuals with pre-existing respiratory disease (asthma). Local corrosion effects are also reported.

Acute symptoms and bronchoconstriction effects are associated with exposure and exercise at 0.5 ppm and 0.4 ppm in individuals with asthma but not at 0.25 ppm (ACGIH, 2019). The STEL of 0.25 ppm recommended by HCOTN (2003) is also based on mouth breathing studies with adjustments for inter-individual differences (reduced by factor of three). Subsequent studies identified by DFG (2012) and SCOEL (2009) indicate significant levels (approximately 90%) that are absorbed *via* the nasal mucosa in normal respiration would minimise the effects on lung function. The LOAEL for lung function changes in healthy human volunteers is 1 ppm, with asthmatics unlikely to experience adverse effects up to 0.75 ppm under normal working conditions (SCOEL, 2009).

There are limited data from human and animal studies to support $SO_2$ as a promoter of carcinogenesis (SCOEL, 2009). Mutagenic effects observed (*in vitro*) are unlikely to occur in human pathological conditions.

Based on the evidence provided and the lack of robust data on chronic effects, a TWA cannot be recommended with good confidence and is recommended to be withdrawn. Based on the evidence of

no effects in asthmatics acutely exposed at 0.25 ppm but effects observed at 0.4 ppm, the STEL of 0.25 ppm by ACGIH (2018) is recommended.

## 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.

There are insufficient data to recommend a skin notation.

# APPENDIX

## Primary sources with reports

| Source | Year set | Standard |
|---|---|---|
| ***SWA*** | ***1991*** | ***TWA: 2 ppm (5.2 mg/m$^3$); STEL: 5 ppm (13 mg/m$^3$)*** |
| | | |
| ***ACGIH*** | ***2009*** | ***TLV-STEL: 0.25 ppm (0.65 mg/m$^3$)*** |

TLV-STEL recommended as being protective for both acute and chronic lung function and irritant respiratory tract effects (and prevent inducing effects in asthmatic individuals during exercise).

Insufficient data to establish TLV-TWA for chronic exposures and relies on TLV-STEL to protect against respiratory effects.

Not classified as carcinogenic based on inconclusive findings of exposed rats and mice.

Insufficient evidence to assign a skin notation.

Summary of data:

Evidence basis for the TLV-STEL:

- Based on acute lung effects (respiratory tract) observed in human subjects under controlled conditions in studies conducted between 1975–1995
- Acute bronchoconstriction effects in subjects with exposure during exercise at 0.5 ppm (and 0.4 ppm in most asthmatic subjects)
- NOEL 0.25 ppm noted in two studies with asthmatic subjects (short term exposures).

Human data:

- Readily absorbed by mucous membranes of respiratory tract; 90% absorbed in the nose
- Frequently reported exposure symptoms include cough, shortness of breath, burning nose eyes and mouth, substernal pain and tearing eyes
- Bronchoconstriction measured by increased flow resistance or reduction in forced expiratory volumes in once second ($FEV_1$)
- Acute symptoms and bronchoconstriction effects demonstrated to be associated with exposure and exercise at 0.5 ppm and 0.4 ppm in subjects with asthma but not at 0.25 ppm
- Epidemiological studies indicate chronic respiratory lung symptoms with long-term exposure between 20–30 ppm
- Loss of smell and taste, fatigue, chronic rhinitis, coughs and increased mucous expectoration noted in refrigeration workers regularly exposed at >5 ppm (with excursion levels >60 ppm)
- Acute exposures >40 ppm for 3.5 h led to fatalities and partially reversible chronic obstructive pulmonary disease
- Transient increase in lysozyme positive macrophages noted in bronchoalveolar lavage fluids after exposure to 4 ppm for 20 min
- No difference in frequency of white blood cell structure changes in 8 foundry workers exposed at average 1 ppm /d compared with 8 controls.

Animal data:

- $LC_{50}$: 150 ppm (mice, 847 h)
- $LC_{50}$: 130 ppm (guinea pigs, 154 h)
- Toxicity noted to be dependent on humidity
- Mucosal damage observed at 20 ppm (mice, 60 min)

| Source | Year set | Standard |
|---|---|---|
| • Repeated exposures, in various tests, produced thickening of mucosal layers of trachea similar to human chronic bronchitis pathological changes<br>• Alterations in mRNA expression of apoptosis related genes in livers at 5 ppm (rats, 6 h/d for 7d)<br>• Increased pulmonary flow resistance and lung compliance with continuous exposures to 5 ppm (dogs, 225 d). | | |
| ***DFG*** | ***2012*** | ***MAK: 1 ppm (2.7 mg/m$^3$)*** |
| MAK updated in 2012 based on additional human volunteer studies conducted in 2010 from previous value (0.5 ppm, 1998) due to exposure conclusions being based on mouth breathing studies (same as ACGIH) determined to be less representative of actual exposures with identified nasal absorption reduction in health effects.<br>Summary of additional data:<br>Human data:<br>• Breathing restriction in asthmatic individuals is impacted by depth and volume of respiration and less related to concentration<br>• Studies indicate 90% $SO_2$ is removed during nasal breathing<br>• No sensory irritation (nose or eyes), impaired lung function or increased nasal resistance reported in 16 volunteers exposed at 0, 0.5 or 2 ppm for 4 h (induced exertion).<br>Animal data:<br>• More effectively removed via nose than mouth alone confirmed in dogs<br>• No embryotoxic or teratogenic effects in CF-1 mice exposed at 25 ppm, on GD 6–15<br>• No embryotoxic or teratogenic effects in rabbits exposed at 70 ppm on GD 6-18 (7 h/d)<br>• Average foetal body weight reduced in mice (1.05 g–1.00 g):<br>o no changes in rabbit offspring. | | |
| ***SCOEL*** | ***2009*** | ***TWA: 0.5 ppm (1.3 mg/m$^3$); STEL: 1.0 ppm (2.7 mg/m$^3$)*** |
| TWA recommended based on observed effects on lung function in healthy people with additional reduction for individuals with compromised lung function.<br>STEL recommended to limit peak exposures causing irritation.<br>No epidemiological evidence as a promoter of carcinogenesis.<br>No skin notation considered necessary.<br>Summary of additional data:<br>Human data:<br>• Inhalation causes reaction with mucosa to form sulphurous acids<br>• Lung function changes in human volunteer studies exposed at 1 ppm:<br>o considered LOAEL<br>• Asthmatics unlikely to experience adverse effects ≤0.75 ppm under normal working conditions (studies ranged from 1–6 h).<br>Animal data:<br>• Mutagenicity tests in bacteria have positive results in non-human physiological conditions (DNA damage with pH changes). | | |

| Source | Year set | Standard |
|---|---|---|
| ***OARS/AIHA*** | ***NA*** | ***NA*** |
| No report. | | |
| ***HCOTN*** | ***2003*** | ***STEL: ≈0.25 ppm (0.7 mg/m$^3$)*** |
| STEL applied to prevent effects on respiratory tract (nose and throat irritation and depressed lung function and increased airway resistance).<br>Insufficient evidence to support concentration-response relationship to determine TWA.<br>Insufficient evidence to support carcinogenicity or skin notation.<br>Human data:<br>• NOAEL identified as 2.0 mg/m$^3$ (0.7 ppm) based on healthy volunteer studies with lung functions remaining normal<br>• NOAEL adjusted by 3 for inter-individual differences.<br>Animal data:<br>• Enzyme changes noted in liver and blood studies. However, quality of animal study records noted to be insufficient<br>• No concentration-response relationships could be established<br>• Notes most animal studies are at significantly higher exposures (>1,000 mg/m$^3$)<br>• Chromosomal aberrations noted *in vitro,* positive genotoxicity and mutagenicity results in bacteria in conditions not relevant to humans. | | |

## Secondary source reports relied upon

| Source | | Year | Additional information |
|---|---|---|---|
| NICNAS | ✓ | 2015 | • Critical health effects identified as local corrosive effects on eyes, skin and respiratory tract<br>• Highly water-soluble gas, rapidly absorbed in the upper respiratory tract, with negligible quantities reaching deeper airways<br>• Endogenous accumulation of sulfite metabolites in the respiratory tract and in plasma of rats found to be less hazardous than the inhaled effect<br>• Multiple non-guideline animal studies exposed to various durations and concentrations *via* inhalation demonstrated a high retention (>95%) in upper airways (nose, mouth and pharynx), with ≈1–5% of the initially inhaled volumes reaching the tracheal regions<br>• Insufficient data for respiratory sensitisation classification<br>• Potential genotoxic effects, however insufficient data to warrant classification. |
| US EPA | ✓ | 2001 | • Data suggests cold dry air in the presence of other particulates with oral breathing (over nasal) may enhance the toxic effects<br>• 0.25 ppm anticipated to be likely threshold for bronchoconstriction in asthmatics with exposure to 0.5 ppm likely to require medication or cessation of activities. |
| ECHA | ✗ | 2020 | No further information. |

| Source | | Year | Additional information |
|---|---|---|---|
| OECD | ✖ | 2019 | No further information. |

### Carcinogenicity — non-threshold based genotoxic carcinogens

| | |
|---|---|
| Is the chemical mutagenic? | Insufficient data |
| Is the chemical carcinogenic with a mutagenic mechanism of action? | Insufficient data |

**Insufficient data are available to determine if the chemical is a non-threshold based genotoxic carcinogen.**

## Notations

| Source | Notations |
|---|---|
| SWA | — |
| HCIS | NA |
| NICNAS | NA |
| EU Annex | NA |
| ECHA | NA |
| ACGIH | Carcinogenicity – A4 |
| DFG | — |
| SCOEL | — |
| HCOTN | Carcinogenicity – category 3 |
| IARC | NA |
| 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 |
|---|
| Insufficient data to assign a skin notation. |

### IDLH

| | |
|---|---|
| Is there a suitable IDLH value available? | Yes |

## Additional information

| | |
|---|---|
| Molecular weight: | 64.06 |
| Conversion factors at 25°C and 101.3 kPa: | 1 ppm = 2.62 mg/m$^3$; 1 mg/m$^3$ = 0.38 ppm |
| This chemical is used as a pesticide: | ☐ |
| This chemical is a biological product: | ☐ |
| This chemical is a by-product of a process: | ✓ |
| 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.

Deutsche Forschungsgemeinschaft (DFG) (2013) Sulfur dioxide – MAK value documentation.

EU Scientific Committee on Occupational Exposure Limits (SCOEL) (2009) Recommendation from the Scientific Committee on Occupational Exposure Limits for Sulphur Dioxide. SCOEL/SUM/27.

European Chemicals Agency Regulation (ECHA) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).

Health Council of the Netherlands (HCOTN) (2003) Sulphur dioxide. Health-based calculated occupational cancer risk values. The Hague: Health Council of the Netherlands; publication no. 2003/08OSH.

National Industrial Chemicals Notification and Assessment Scheme (NICNAS) (2015) Sulfur dioxide: Human health tier II assessment – IMAP report.

Organisation for Economic Cooperation and Development (OECD) (2019) SIDS initial assessment profile – Sulfur dioxide.

US Environmental Protection Authority (US EPA) (2010) Sulfur Dioxide - Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 8.

US National Institute for Occupational Safety and Health (NIOSH) (1994) Immediately dangerous to life or health concentrations – Sulfur dioxide.