Sulphur dioxide (SO\textsubscript{2}) is a colourless gas at room temperature and a colourless liquid when pressurized or cooled. It is a non-flammable, very soluble gas with an irritating, pungent acid odour and taste. SO\textsubscript{2} has many industrial and agricultural uses and is derived from the combustion of sulphur-containing fossil fuels, which are not commonly used indoors. SO\textsubscript{2} gas is produced as a by-product during the smelting and converting processes.

Domestic indoor air levels of SO\textsubscript{2} rarely exceed 30% of outdoor/industrial levels unless an unvented kerosene burner is used with extremely low-grade fuel. Most indoor exposure in the workplace results from the misuse of equipment, including inadequate venting of oil-burning combustion appliances.

When released into the environment, sulphur dioxide moves into the air. In the air, it can be converted to sulphuric acid, sulphur trioxide, and sulphates. SO\textsubscript{2} dissolves easily in water and can react with moisture on the skin and other moist surfaces of the human body to form sulphuric acid. Some foods and drinks are preserved with small quantities of SO\textsubscript{2} that are safe for human consumption.

Exposure to SO\textsubscript{2} can occur in industry and mining when workers are exposed to the following industries and/or substances (in most cases SO\textsubscript{2} is a by-product):

<table>
<thead>
<tr>
<th>Substance</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antioxidants</td>
<td>Mining</td>
</tr>
<tr>
<td>Bleaching agents</td>
<td>Ore smelters</td>
</tr>
<tr>
<td>Chemical synthesis</td>
<td>Coke ovens</td>
</tr>
<tr>
<td>Disinfectants</td>
<td>Foundries</td>
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<tr>
<td>Food additives</td>
<td>Ore refining</td>
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<tr>
<td>Fumigant</td>
<td>Power plants</td>
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<tr>
<td>Solvents</td>
<td></td>
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<tr>
<td>Exhaust emissions</td>
<td></td>
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</tbody>
</table>

To protect employees against the ill health effects of SO\textsubscript{2} exposure, they are often required to make use of respiratory protection whenever entering areas where the SO\textsubscript{2} levels exceed the statutory limits. The use of respiratory protective equipment should always be a last resort and should be considered only after other control measures have failed to reduce occupational exposure levels to below the occupational exposure limit or whilst other control measures are being investigated or implemented.

Exposure routes

Occupational exposure to SO\textsubscript{2} can occur via inhalation, skin and/or eye contact.

Symptoms

Symptoms of exposure to SO\textsubscript{2} could include irritation of the eyes, nose and throat; rhinorrhea (discharge of thin mucus); choking; cough; and reflex bronchoconstriction.

Exposure to SO\textsubscript{2} in a liquid form could result in frostbite.
### Occupational health and safety risks associated with sulphur dioxide

#### Target organs
SO₂ target organs are the eyes, skin and respiratory system.

#### People at risk
The following situations place people at risk:
- Breathing air contaminated with SO₂ or coming into contact with SO₂
- Working in industries where it occurs as a by-product, such as copper smelting and power plants
- Working in the manufacture of sulphuric acid, paper, food preservatives, or fertilizers
- Living near heavily industrialized activities where SO₂ occurs
- In nature, SO₂ can be released into the atmosphere from volcanic eruptions.

#### Effects of short-term (acute) exposure
SO₂ is a moderate to strong irritant of the respiratory system. Most inhaled SO₂ penetrates only as far as the nose and throat with minimal amounts reaching the lungs, unless a person is breathing heavily, breathing only through the mouth or the concentration of SO₂ to which the person is exposed is high.

Sensitivity varies among people, however, short exposure (1–6 hours) to concentrations as low as 1 parts per million (ppm)¹ may produce a reversible decrease in lung function. A 10 to 30 minute exposure to concentrations as low as 5 ppm has produced constriction of the bronchiole tubes. About 20 ppm is objectionable, irritating, although people have been reported to work in concentrations exceeding 20 ppm. Concentrations of 6–12 ppm cause immediate irritation to the nose and throat, while 0.3–1 ppm can be detected by the average individual, possibly by taste rather than smell. Burning of the nose and throat, breathing difficulties, and airway obstruction are common symptoms reported by miners who breathed SO₂ released as a result of blasting.

Fifty ppm is so objectionable that a person cannot inhale a single deep breath. In severe cases where very high concentrations of SO₂ have been produced in closed or confined spaces, SO₂ has caused severe airway obstruction, hypoxemia (insufficient oxygenation of the blood), pulmonary oedema (a life threatening accumulation of fluid in the lungs), and death in minutes. The effects of pulmonary oedema include coughing and shortness of breath, which can be delayed until hours or days after the exposure. These symptoms are aggravated by physical exertion. As a result of severe exposures, permanent lung injury may occur.

Asthmatic has been shown to be sensitive to the respiratory effects of low concentrations of SO₂.

Exposure to 100 ppm SO₂ is considered immediately dangerous to life and health. The chosen IDLH is based on the statement by American Industrial Hygiene Association (AIHA) (1955) that 50 to 100 ppm SO₂ is considered the maximum concentration for exposures of 0.5 to 1 hour (Henderson and Haggard, 1943). With regard to the atmospheric concentration immediately hazardous to life, AIHA (1955) reported that 400 to 500 ppm is considered dangerous for even short periods of exposure (Henderson and Haggard, 1943) and that exposure to unendurable concentrations is not necessarily hazardous if escape is made within a few minutes.

#### Effects of long-term (chronic) exposure
The following respiratory effects have been proven to occur as a result of chronic exposure to SO₂:
- Chronic exposure can result in an altered sense of smelling (including increased tolerance of low levels of SO₂)
- Increased susceptibility to respiratory infections
- Several human studies have shown that repeated exposure to low levels of SO₂ (below 5 ppm) has caused permanent pulmonary impairment. This effect is probably due to repeated episodes of bronchoconstriction
- Chronic bronchitis
- Accelerated decline in pulmonary function
- Repeated or prolonged inhalation exposure may cause asthma
- Emphysema.

#### Hazardous classification
There are no studies to date that clearly indicate any carcinogenic effects in humans or animals as a result of SO₂ exposure. Studies have investigated workers in the copper smelting and pulp and paper industries, but the results were inconclusive since the workers were also exposed to arsenic and other chemicals.

The International Agency for Research on Cancer (IARC) has classified SO₂ as a Group 3 substance, i.e. SO₂ is not classifiable as a human carcinogen.

#### Occupational exposure limit (OEL)
Occupational exposures to airborne SO₂ are evaluated against the occupational exposure limits (OELs) prescribed in the Regulations for Hazardous Chemical Substances, 1995, of the Occupational Health and Safety Act No. 85 of 1995, and the OEL prescribed in Schedule 22.9(2)(a) of the Regulations of the Mine Health and Safety Act No. 29 of 1996. For SO₂ an OEL-TWA² of 2 ppm is prescribed.

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¹ppm is defined as the parts (amount) of a substance per million parts of air.

²An occupational exposure level refers to the time weighted average airborne concentration of a chemical substance for an 8-hour work day and a 40-hour work week and represents conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse health effects. The term ‘8-hour reference period’ relates to the procedure whereby the occupational exposures in any 24-hour period are treated as equivalent to a single uniform exposure of 8 hours (the 8-hour time weighted average (TWA) exposure).
### Occupational health and safety risks associated with sulphur dioxide

**Control measures**

**Respirator zoning**

Areas or work places where concentrations of SO₂ in the ambient atmosphere exceed the set TWA-OEL of SO₂ being 2 ppm, should be identified as respirator zones and should be demarcated as such, by positioning the appropriate symbolic safety signs, indicating compulsory wearing of respiratory protective devices, in conspicuous places inside and at the entrances to the area. No person should be allowed to enter a respiratory zone, irrespective of duration, unless such a person is wearing the required respiratory protection.

**Engineering control measures**

Excessive SO₂ exposure should be prevented by elimination at the source, i.e. by means of ventilation extraction systems, including at-source extraction hoods. In order to prevent the reintroduction of extracted SO₂ into the workplace air, such extraction systems should be fitted with exhaust air filtering devices, preferably electrostatic precipitators. The design of any SO₂ extraction system should be as such that emissions are removed at source, at a capture velocity of at least 0.75 m/s.

**Respiratory protective equipment (RPE)**

If the use of engineering control measures does not provide the required control of an inhalation hazard, respirators should be considered. Typically respirators are used:

- to reduce exposure until engineering controls are installed
- to supplement engineering controls and work practices which fail to reduce the hazard to an acceptable level
- during activities such as maintenance and repairs, when engineering controls are not feasible
- during emergencies and
- when measures and procedures necessary to control the exposure do not exist or are unavailable.

Since respiratory protection depends upon the proper use of the equipment; all prospective users must be carefully trained in its use, limitations and maintenance and undergo regular retraining, RPE must meet governmental requirements. These can differ worldwide. Programmes for the care and maintenance of RPE are critical to continued effectiveness.

Regarding the issuing of RPE, the following must also be ensured:

- the equipment must be correctly selected and properly used
- employees must receive the information, instruction, training and supervision that are necessary for the use of the equipment
- the equipment must be kept in good condition and efficient working order
- reusable equipment may not be issued, to any person, unless the equipment has been properly decontaminated and sterilized

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The assigned protection factor (APF) of a respirator reflects the level of protection that a properly functioning respirator would be expected to provide to a population of properly fitted and trained users. For example, an APF of 10 for a respirator means that a user could expect to inhale no more than one tenth of the airborne contaminant present.

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The National Institute for Occupational Safety and Health (NIOSH) (USA) recommends the following respiratory protection equipment for protecting employees against excessive exposure to SO₂:

- **Up to 20 ppm**—(Assigned Protection Factor+ (APF = 10)) Any chemical cartridge respirator with cartridge(s) providing protection against the compound of concern.
- **Up to 50 ppm**—(APF = 25) Any supplied-air respirator operated in a continuous-flow mode.
- **Up to 100 ppm**—(APF = 50) Any chemical cartridge respirator with a full face piece and cartridge(s) providing protection against the compound of concern.

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1 The assigned protection factor (APF) of a respirator reflects the level of protection that a properly functioning respirator would be expected to provide to a population of properly fitted and trained users. For example, an APF of 10 for a respirator means that a user could expect to inhale no more than one tenth of the airborne contaminant present.
Occupational health and safety risks associated with sulphur dioxide

➤ Escape—(APF = 50) Any air-purifying, full-face piece respirator (gas mask) with a chin-style, front- or back-mounted canister providing protection against the compound of concern/Any appropriate escape-type, self-contained breathing apparatus.

Half-mask air purifying (filtering) respirator (cartridge type)

This item depends on the removal of a contaminant from the air prior to breathing, i.e. an air purifying device in which the inhaled air is drawn through a medium that removes the contaminant, the nature of the medium depending on the contaminant. Both particulate filters and gas absorbers (and combinations) are available and can be connected to a variety of face pieces.

Cartridge type respirators consist of a half mask (or full mask) connected to a replaceable cartridge (or cartridges) containing absorbent or adsorbent material. A particulate filter is incorporated and for some applications a readily replaceable pre-filter is also incorporated. Gas filters are (i) designated by letter as one of the types listed in Table I, relevant to the main field of application, (ii) colour coded as per indication in Table I and, (iii) of one of the classes listed in Table II, relevant to the gas absorption capacity given in Table II.

Medical surveillance

Additional to the initial health evaluation (immediately before or within 14 days after a person commences with employment), employees exposed to significant levels of SO₂ should be subjected to biological monitoring, at intervals not exceeding two years, or at intervals specified by an occupational medicine practitioner. It is imperative to compile a database of an employee's medical history.

Exclusions

Employees with the following conditions should be excluded from working in an area where they will be exposed to SO₂:

➤ eye disease
➤ skin disease and
➤ pulmonary disease.

Biological monitoring

SO₂ in the human body is changed into sulphur-containing chemicals in the body. These breakdown products can be measured in both blood and urine, but this requires special equipment that is not routinely available in a doctor’s consulting room. Furthermore, exposure to chemicals other than SO₂ can also produce sulphate, so the presence of sulphate breakdown products in a person’s body does not necessarily mean he has been excessively exposed to SO₂.

Information and training

After consulting with the health and safety committee established for that section of the workplace, and before any employee is exposed to or may be exposed to SO₂, it must be ensured that the employee is adequately and comprehensively informed and trained, and thereafter be informed and trained at intervals as may be recommended by the health and safety committee, about:

➤ the contents and scope of legislation pertaining to excessive exposure to SO₂
➤ the potential sources of SO₂ exposure
➤ the potential risks to health caused by exposure
➤ the potential detrimental effect of exposure on his or her reproductive ability
➤ the measures to be taken by the employer to protect employee against any risk from exposure
➤ the precautions to be taken by an employee to protect himself or herself against the health risks associated with the exposure, including the wearing and use of protective clothing and respiratory protective equipment
➤ the necessity, correct use, maintenance and potential of safety equipment, facilities and engineering control measures provided
➤ the necessity of personal air sampling and medical surveillance

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<tr>
<th>Table I</th>
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<tbody>
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<td>Types of gas filters</td>
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<tr>
<td>Type</td>
</tr>
<tr>
<td>A</td>
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<tr>
<td>B</td>
</tr>
<tr>
<td>E</td>
</tr>
<tr>
<td>K</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Table III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classes of gas filters</td>
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<tr>
<td>Gas filter class</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Table III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classes of combination filters</td>
</tr>
<tr>
<td>Filter class</td>
</tr>
<tr>
<td>P1*</td>
</tr>
<tr>
<td>P2</td>
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<tr>
<td>P3</td>
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</tbody>
</table>

* The letter F may be used instead of the preferred letter P designation.
Occupational health and safety risks associated with sulphur dioxide

➤ the importance of good housekeeping at the workplace and personal hygiene and
➤ procedures to be followed in the event of emergency situations.

Duties of persons who may be excessively exposed to SO\textsubscript{2}

Every person who is or may be excessively exposed to SO\textsubscript{2} shall obey any lawful instruction given by or on behalf of the employer or a self-employed person, about:
➤ the prevention of SO\textsubscript{2} being released in the ambient atmosphere of the workplace
➤ the wearing of personal protective equipment
➤ the wearing of monitoring equipment to measure personal exposure
➤ the reporting for health evaluations and biological tests
➤ housekeeping at the workplace, personal hygiene and environmental and health practices.

Records

Records of risk assessments, exposure monitoring and all medical surveillance records, including the baseline medical tests of every employee, must be kept for a minimum period of 40 years. If the employer ceases activities, his records must be handed over to the relevant provincial director, providing that those records shall contain at least the following information:
➤ each employee’s surname, forenames, gender, date of birth, name of spouse or closest relative and, where available, permanent address and postal code
➤ a record of the type of work carried out that caused occupational exposure to SO\textsubscript{2}
➤ a record of any previous work-related hazardous chemical substance exposure prior to an employee’s current employment and
➤ the dates of medical surveillance and results of all such tests.

Records of training given to an employee, as detailed above, must be kept for as long as the employee remains employed at the workplace in which he or she is being exposed to SO\textsubscript{2} or other hazardous chemical substances.

Reports on surveys and maintenance performed on engineering control measures, must be kept for three years.

Follow-up and review

Employers should review, and if necessary, modify their risk assessments and exposure assessment strategies since these should not be a once-off activity. Risk assessment and exposure assessments are continuous processes, as processes and activities changes, then the hazards and risks may change, and therefore the risk assessment process must change. If an accident occurs, or if more is learned about the hazards in the workplace, risk assessments need to be reviewed and modified.

Occupational health risk assessments and exposure assessment strategies must be reviewed if:
➤ there exists any reason for questioning a previous assessment
➤ there are any changes or developments that suggest that the assessments may no longer be valid or that it can be improved, including process changes.

Furthermore, it is good practice to plan to review risk assessments at regular interviews—the time between reviews being dependant upon the nature of the risks and the degree of change likely to take place in the work activity and/or process. Deemed best practice for a reassessment to be carried out in the absence of any significant change to the workplace, process, activity or task(s) is once every twenty-four months. Such reviews are part of good management practice.

Conclusion

SO\textsubscript{2} is often seen by industry as nothing more than a health (and to a lesser extent safety) irritant associated with the generation and handling of sulphur dioxide and the manufacturing of sulphuric acid. The toxicological properties of SO\textsubscript{2} are either misunderstood or ignored by employers. This can be fatal. Whenever there is a possibility of excessive exposure, appropriate control and management programmes must be put in place.

References


Tab Biol Per; 5:231 (in German). 1933.