Occupational health and safety risks associated with sulphur dioxide

by C.J. Badenhorst*

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Synopsis

Oxides of sulphur are corrosive and are produced when sulphur-containing fuels are burned. Sulphur dioxide (SO_2) is a colourless gas with a characteristic, irritating, pungent odour. Exposure routes to the human body are mainly through inhalation and skin and/or eye contact. Symptoms of exposure to SO_2 may include irritation of the eyes, nose, and throat; rhinorrhea (discharge of thin nasal mucous); choking; cough; and reflex bronchoconstriction.

To protect employees against the ill health effects of SO_2 exposure, they are often required to make use of respiratory protection whenever entering areas were the SO_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.

Whenever the use of respiratory protection equipment is considered, it should always be used as part of a comprehensive respiratory protection plan. It is also extremely important that all potentially exposed persons are adequately and comprehensively informed and trained.

Introduction

Sulphur dioxide (SO_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_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_2 gas is produced as a by-product during the smelting and converting processes.

Domestic indoor air levels of SO_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_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_2 that are safe for human consumption.

Exposure to SO_2 can occur in industry and mining when workers are exposed to the following industries and/or substances (in most cases SO_2 is a by-product):

Substance	Industry
Antioxidants	Mining
Bleaching agents	Ore smelters
Chemical synthesis	Coke ovens
Disinfectants	Foundries
Food additives	Ore refining
Fumigant	Power plants
Solvents	
Exhaust emissions	

Exposure routes

Occupational exposure to SO_2 can occur via inhalation, skin and/or eye contact.

Symptoms

Symptoms of exposure to SO_2 could include irritation of the eyes, nose and throat; rhinorrhea (discharge of thin mucus); choking; cough; and reflex bronchoconstriction. Exposure to SO_2 in a liquid form could result in frostbite.

* *Anglo Platinum Limited.*

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Occupational health and safety risks associated with sulphur dioxide

Target organs

SO_2 target organs are the eyes, skin and respiratory system.

People at risk

The following situations place people at risk:

- Breathing air contaminated with SO_2 or coming into contact with SO_2
- 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 SO_2 occurs
- In nature, SO_2 can be released into the atmosphere from volcanic eruptions.

Effects of short-term (acute) exposure

SO_2 is a moderate to strong irritant of the respiratory system. Most inhaled SO_2 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 SO_2 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 SO_2 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 SO_2 have been produced in closed or confined spaces, SO_2 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.

Asthmatics have been shown to be sensitive to the respiratory effects of low concentrations of SO_2.

Exposure to 100 ppm SO_2 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 SO_2 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 SO_2:

- Chronic exposure can result in an altered sense of smelling (including increased tolerance of low levels of SO_2)
- Increased susceptibility to respiratory infections
- Several human studies have shown that repeated exposure to low levels of SO_2 (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 SO_2 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 SO_2 as a Group 3 substance, i.e. SO_2 is not classifiable as a human carcinogen.

Occupational exposure limit (OEL)[2]

Occupational exposures to airborne SO_2 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 SO_2 an OEL-TWA[3] of 2 ppm is prescribed.

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

[2]An 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.

[3]TWA is the time weighted average for an 8-hour reference period. 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).

Control measures

Respirator zoning

Areas or work places where concentrations of SO_2 in the ambient atmosphere exceeds the set TWA-OEL of SO_2, 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 SO_2 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 SO_2 into the workplace air, such extraction systems should be fitted with exhaust air filtering devices, preferably electrostatic precipitators. The design of any SO_2 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
- separate containers or storage facilities for RPE, when not in use, must be provided and
- it must be ensured that no person removes dirty or contaminated RPE from the premises. Provided that where contaminated RPE has to be disposed of, it shall be treated as hazardous waste.

Respirator recommendations for protection against SO_2

The National Institute for Occupational Safety and Health (NIOSH) (USA) recommends the following respiratory protection equipment for protecting employees against excessive exposure to SO_2:

- *Up to 20 ppm*—(Assigned Protection Factor[4] (APF = 10)) Any chemical cartridge respirator with cartridge (s) providing protection against the compound of concern.
  (APF = 10) Any supplied-air respirator.
- *Up to 50 ppm*—(APF = 25) Any supplied-air respirator operated in a continuous-flow mode.
  (APF = 25) Any powered, air-purifying respirator with cartridge(s) providing protection against the compound of concern.
- *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.
  (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.
  (APF = 50) Any powered, air-purifying respirator with a tight-fitting face piece and cartridge(s) providing protection against the compound of concern.
  (APF = 50) Any supplied-air respirator that has a tight-fitting face piece and is operated in a continuous-flow mode.
  (APF = 50) Any self-contained breathing apparatus with a full face piece.
  (APF = 50) Any supplied-air respirator with a full face piece.
- *Emergency or planned entry into unknown concentrations or IDLH conditions*—(APF = 10 000) Any self-contained breathing apparatus that has a full face piece and is operated in a pressure-demand or other positive-pressure mode.
  (APF = 10 000) Any supplied-air respirator that has a full face piece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus.

[4]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.

- *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.

Table I

Types of gas filters

Type	Colour	Main field of application
A	Brown	Organic gasses and vapours, e.g. solvents
B	Grey	Inorganic gases and vapours, e.g. chlorine
E	Yellow	Sulphur dioxide, hydrogen chloride
K	Green	Ammonia

Table III

Classes of gas filters

Gas filter class	Gas absorption capacity
1	Small
2	Medium
3	Large

Table III

Classes of combination filters

Filter class	Inward leakage value, %, max
P1*	20
P2	6
P3	0.06

* The letter F may be used instead of the preferred letter P designation.

A combination filter shall, in addition to the type and class designations, be designated as on of the classes given in Table III, relevant to the inward leakage value.

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 SO_2 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 SO_2:

- eye disease
- skin disease and
- pulmonary disease.

Biological monitoring

SO_2 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 SO_2 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 SO_2.

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 SO_2, 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 SO_2
- the potential sources of SO_2 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

- 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_2

Every person who is or may be excessively exposed to SO_2 shall obey any lawful instruction given by or on behalf of the employer or a self-employed person, about:

- the prevention of SO_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_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_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_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_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.

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