NITRIC OXIDE	ICSC: 1311

Date of Peer Review: November 1998

Nitrogen oxide
Mononitrogen monoxide
(cylinder)

CAS #	10102-43-9	NO
RTECS #	QX0525000	Molecular mass: 30.01
UN #	1660	
EC #		

TYPES OF HAZARD / EXPOSURE	ACUTE HAZARDS / SYMPTOMS	PREVENTION	FIRST AID / FIRE FIGHTING
FIRE	Not combustible but enhances combustion of other substances.		In case of fire in the surroundings: use appropriate extinguishing media.
EXPLOSION			In case of fire: keep cylinder cool by spraying with water. Combat fire from a sheltered position.
EXPOSURE		**STRICT HYGIENE!**	
Inhalation	Abdominal pain. Cough. Headache. Drowsiness. Burning sensation. Nausea. Dizziness. Confusion. Blue skin. Blue lips or finger nails. Shortness of breath. Convulsions. Unconsciousness. Symptoms may be delayed (see Notes).	Ventilation, local exhaust, or breathing protection.	Fresh air, rest. Half-upright position. Artificial respiration may be needed. Refer for medical attention.
Skin			Refer for medical attention.
Eyes	Redness.	Safety goggles or eye protection in combination with breathing protection.	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then take to a doctor.
Ingestion			

SPILLAGE DISPOSAL	PACKAGING & LABELLING

Gas-tight chemical protection suit including self-contained breathing apparatus.	**EU Classification** **UN Classification** UN Hazard Class: 2.3 UN Subsidiary Risks: 5.1 and 8
EMERGENCY RESPONSE	**SAFE STORAGE**
Transport Emergency Card: TEC (R)-20S1660 or 20G1TOC NFPA Code: H3; F0; R0; OX	Fireproof if in building. Keep in a well-ventilated room.

IPCS
International Programme on Chemical Safety

UNEP

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NITRIC OXIDE — ICSC: 1311

IMPORTANT DATA

PHYSICAL STATE; APPEARANCE:
COLOURLESS COMPRESSED GAS

CHEMICAL DANGERS:
The substance is a strong oxidant and reacts with combustible and reducing materials. On contact with air it emits nitrogen dioxide.

OCCUPATIONAL EXPOSURE LIMITS:
TLV: 25 ppm as TWA; BEI issued; (ACGIH 2004).

ROUTES OF EXPOSURE:
The substance can be absorbed into the body by inhalation.

INHALATION RISK:
A harmful concentration of this gas in the air will be reached very quickly on loss of containment.

EFFECTS OF SHORT-TERM EXPOSURE:
The substance is irritating to the eyes and the respiratory tract. Inhalation of the substance may cause lung oedema (see Notes). The substance may cause effects on the blood, resulting in formation of methaemoglobin. Exposure may result in death. The effects may be delayed. Medical observation is indicated.

EFFECTS OF LONG-TERM OR REPEATED EXPOSURE:
Lungs may be affected by repeated or prolonged exposure.

PHYSICAL PROPERTIES

Boiling point: -151.8℃
Melting point: -163.6℃
Solubility in water, ml/100 ml at 0℃: 7.4
Relative vapour density (air = 1): 1.04

ENVIRONMENTAL DATA

NOTES
The symptoms of lung oedema often do not become manifest until a few hours have passed and they are aggravated by physical effort. Rest and medical observation is therefore essential. Immediate administration of an appropriate inhalation therapy by a doctor or a person authorized by him/her, should be considered. Specific treatment is necessary in case of poisoning with this substance; the appropriate means with instructions must be available. No odour warning if toxic concentrations are present. Card has been partly updated in April 2005. See sections Occupational Exposure Limits, Emergency Response.
ADDITIONAL INFORMATION
LEGAL NOTICE Neither the CEC nor the IPCS nor any person acting on behalf of the CEC or the IPCS is responsible for the use which might be made of this information

NITROGEN OXIDES

International Programme on Chemical Safety
Poisons Information Monograph (Group Monograph) G017
Chemical

1. NAME

1.1 Substance

Nitrogen oxides

1.2 Group

Nitric oxide
Nitrous oxide
Nitrogen dioxide
Nitrogen pentoxide

1.3 Synonyms

Nitiric oxide: mononitrogen monoxide;
nitrogen monoxide

Nitrous oxide: dinitrogen monoxide:
laughing gas; factitious air;
hyponitrous acid anhydride;
mononitrogen monoxide; nitric oxide;
nitrogen oxide;

Nitrogen pentoxide: dinitrogen pentoxide;
nitric anhydride;

Nitrogen dioxide: nitrogen tetroxide

1.4 Identification numbers

1.4.1 CAS number

Nitric oxide	10102-43-9
Nitrous oxide	10024-97-2
Nitrogen dioxide	10102-44-0

1.4.2 Other numbers

1.5 Brand names, Trade names

1.6 Manufacturers, Importers

2. SUMMARY

2.1 Main risks and target organs

Inhalation of any oxides of nitrogen causes toxic effects. The main target organ is the lung.

2.2 Summary of clinical effects

There may be three stages of toxicity. Initially there may be mild irritation of the upper respiratory tract, cough, sore throat, conjunctivitis, dyspnoea, headache,

vertigo, and tightness of the chest.

After a latent period of 3 to 30 hours, inflammation of the lungs, pulmonary oedema, dyspnoea, wheezing and cyanosis resulting in severe respiratory failure.

Approximately half the patients who survive pulmonary oedema develop bronchiolitis obliterans within a few weeks.

2.3 Diagnosis

Diagnosis depends on a history of exposure and the presence of symptoms and signs related to the respiratory system.

Arterial blood gas studies may show hypoxia, hypercapnia and acidosis.

Pulmonary function tests may show obstructive, restrictive and diffusion defects.

2.4 First-aid measures and management principles

First-aid measures:

Remove the patient to from the source of exposure and admit to hospital as soon as possible.

Management principles:

Establish an adequate airway and maintain respiration.
Give oxygen and assisted ventilation if necessary. Treat bronchospasm with bronchodilators.
Remove secretions.
Give corticosteroids if moderate respiratory symptoms or pulmonary oedema are present.
Keep under observation.

3. PHYSICO-CHEMICAL PROPERTIES

3.1 Origin of the substance

Oxides of nitrogen are synthesized or occur as by-products of chemical processes or fires.

On a global scale, quantities of nitric oxide and nitrogen dioxide produced naturally by bacterial and volcanic action and by lightning by far outweigh those generated by man's activities (WHO, 1977).The major source of man-made emission of oxides of nitrogen is the combustion of fossil fuels in stationary sources (heating, power generation) and in motor vehicles (internal combustion engines).Other sources are industrial processes such as manufacture of nitric acid and explosives, smoking, gas-fired appliances and oil stoves.

Burning plastics, shoe polish, nitrocellulose, and welding operations produce oxides of nitrogen (Horvath, 1980).

Nitric oxide is prepared industrially by passing air through an electric arc or by oxidation of ammonia over platinum gauze.

Laboratory preparation is by reacting sodium nitrite with ferrous sulphate.

Nitrous oxide is prepared by thermal decomposition of ammonium nitrate.

Nitrogen dioxide is prepared industrially from nitric oxide and in the laboratory from lead nitrate.

Nitrogen pentoxide is produced by dehydration of nitric acid by phosphorus pentoxide (Budavari, 1996).

3.2 Chemical structure

Nitric oxide
Molecular weight 30.01

Nitrogen dioxide
Molecular weight 44.02

Nitrogen pentoxide
Molecular weight 108.02

3.3 Physical properties

3.3.1 Colour

See section 3.3.3

3.3.2 State/form

See section 3.3.2

3.3.3 Description

Nitrogen dioxide
Molecular formula: NO_2
Boiling point 21.15°C
Melting point -9.3°C
Molecular mass 44.02
Condensation point 21°C
Specific gravity at 20°C 1.448 (liquid)

A reddish brown gas. Liquid below 21.15°C.

Nitrogen pentoxide
Molecular formula: N_2O_5
Boiling point 47.0°C
Melting point 30°C
Molecular mass 108.02

Colourless hexagonal crystals.

Nitrous oxide
Molecular formula: N_2O
Boiling point 88.46°C
Melting point -90.81°C
Vapour pressure (Pascals at 20°C) 4.93 (Mellor, 1967)
Solubility: Soluble in alcohol and ether.

A colourless gas with slightly sweetish odour and taste.

Nitric oxide

Molecular formula	NO
Boiling point:	-151.8 °C
Molecular mass:	30.01

A colourless gas.

(Budavari, 1996)

3.4 Hazardous characteristics

Nitrogen dioxide
It has an irritating odour and is highly poisonous.Under normal atmospheric conditions it exists in equilibrium with nitrogen tetroxide (N_20_4). Heavier than air. Nitrogen dioxide produces nitrous acid ($HN0_2$) and nitric acid ($HN0_3$) on contact with water.

Nitrogen pentoxide
Sublimes at -32.4°C but undergoes moderately rapid decomposition into 02 and the NO_2/N_20_4 equilibrium mixture at temperatures above -10°C. Freely soluble in chloroform without appreciable decomposition.

Nitrous oxide
Supports combustion.Very stable and rather inert chemically at room temperatures.Dissociation begins above 300°C when the gas becomes a strong oxidizing agent.

Nitric oxide
Burns when heated with hydrogen. It combines with oxygen to form nitrogen dioxide and with halogens to form nitrosyl halides, e.g. NOCl.

(Budavari, 1996)

4. USES/CIRCUMSTANCES OF POISONING

4.1 Uses

4.1.1 Uses

4.1.2 Description

Nitric oxide
In the manufacture of nitric acid, bleaching of rayon; as a stabilizer (to prevent free radical decomposition) for propylene, methyl ether etc.

Nitrogen dioxide
Intermediate in nitric and sulphuric acid production. It is also used in nitration of organic compounds and explosives in the manufacturing of oxidized cellulose compounds. Has been used to bleach flour. Proposed as oxidizing agent in rocket propulsion.

Nitrogen pentoxide

Used in chloroform solution as a nitrating agent.

Nitrous oxide
To oxidize organic compounds at temperatures above 300°C to make nitrites from alkali metals at their boiling points, in rocket fuel formulations (with carbon disulphide) and in the preparation of whipped cream. Also used as an anaesthetic gas (Budavari, 1996).

4.2 High risk circumstance of poisoning

Poisoning occurs following exposure to industrial, manufacturing or agricultural sources which evolve nitrous fumes (oxides of nitrogen).

Nitrogen dioxide and nitric oxide are the principal hazards. Nitrous oxide is narcotic in high concentrations but it is less irritant than other oxides of nitrogen.

4.3 Occupationally exposed populations

Occupational exposure usually occurs from manufacture of dyes, fertilizers, celluloid and lacquers; and from welding glass blowing and food bleaching.

Firemen may be exposed to nitrogen oxide during chemical plant fires or from burning mattresses (Ellenhorn & Barceloux, 1988).

Nitrogen oxides are also released from processes such as electroplating, engraving, photogravure operations etc. (Gosselin et al., 1984).

Severe symptoms and death has been reported in farmers working in or near silos. This syndrome, known as silo filler's disease, is due to acute exposure to oxides of nitrogen produced by silage (Ellenhorn & Barceloux 1988).

Occupational exposure occurs in anaesthesia.

5. ROUTES OF ENTRY

5.1 Oral

Not known.

5.2 Inhalation

Inhalation of some oxides of nitrogen such as nitric oxide and nitrogen dioxide causes poisoning. On contact with air, nitric oxide is converted to highly poisonous nitrogen dioxide.

The effects of nitrogen dioxide are insidious: inhalation may cause only slight pain or go unnoticed, but may cause death later.

5.3 Dermal

Nitric acid , formed when fumes of nitrogen oxides mix

with sweat, has caused skin burns (Haddad and Winchester, 1990).

5.4 Eye

Fumes of nitrogen oxides can cause eye irritation (Haddad and Winchester, 1990).

5.5 Parenteral

Not known.

5.6 Others

Not known.

6. KINETICS

6.1 Absorption by route of exposure

Nitrogen oxides are largely absorbed by and react with pulmonary alveolar structures and terminal respiratory bronchioles.

They are less soluble than most irritant gases and have a greater tendency to reach the bronchioles and alveoli (Haddad and Winchester, 1990).

6.2 Distribution by route of exposure

Within the lungs, nitrogen oxides react with water to form nitrous and nitric acids causing extensive local damage.

6.3 Biological half-life by route of exposure

The biological half-life of endogenous nitrogen oxides in vascular endothelium is very short.

6.4 Metabolism

No data available.

6.5 Elimination by route of exposure

No data available.

7. TOXICOLOGY

7.1 Mode of Action

Of the five principal oxides of nitrogen, nitrous oxide is comparatively harmless. The principal target organ for other oxides is the lung. Nitric oxide is less toxic tot he lung than nitrogen dioxide. Little is known about toxicology of nitrogen trioxide (N_2O_3) and nitrogen pentoxide (N_2O_5) (Gosselin et al., 1984).

It is now generally accepted that nitrogen dioxide is the principal causative factor of the pulmonary changes following the inhalation of oxides of nitrogen ("nitrous fumes")

(Milne, 1969).

Nitrogen oxides are irritant and destructive to lung tissues because they are slowly hydrolysed to acids. The upper respiratory tract is largely spared perhaps because these gases have a low solubility in aqueous media and because they are only slowly hydrolysed.

The mild upper respiratory irritant effect is a result of nitrogen dioxide being converted to nitric acid in the presence of water.

Nitric acid destroys respiratory epithelium and alveolar membranes and may produce metabolic acidosis. The mild initial irritant effects allow widespread dissemination of nitrogen oxides throughout the lungs and result in diffuse delayed inflammation.

Fibrotic destruction of terminal bronchioles (bronchiolitis obliterans) occurs as a late complication (Ellenhorn & Barceloux, 1988).

Nitrogen dioxide decomposition may also produce nitrates which are capable of causing vasodilatation and mild methaemoglobinaemia.

7.2 Toxicity

7.2.1 Human data

7.2.1.1 Adults

The presence of nitrogen dioxide may be difficult to perceive and it is frequently undetectable at concentrations causing mucosal irritation. Early symptoms are often mild, even in cases where there is serious late toxicity. At levels of 100 to 150 ppm toxicity occurs within 30 to 60

minutes and at levels of 200 to 700 ppm fatalities result after short exposure (Ellenhorn & Barceloux, 1988).

Chest discomfort occurs after exposure to 15 ppm for 1 hour and the sensation becomes unpleasant at 25 ppm. After 1 minute at 50 ppm subjects feel substernal pain. Longer exposure at this concentration causes reversible inflammatory changes in the lungs. Higher concentrations may be fatal (Dreisbach, 1987).

7.2.1.2 Children

No data available.

7.2.2 Relevant animal data

In the rat, exposure to 0.5 ppm for 4 hours causes reversible degranulation of lung cells. Mice

exposed continuously for 3 months to 0.5 ppm become more susceptible to infection when challenged with pneumococci. Weight loss occurs in monkeys exposed to this concentration but other animals are not affected.

In the rat, continuous exposure to 2 ppm of NO_2 for 3 days caused epithelial hyperplasia in the terminal bronchioles. Exposure for more than one year caused thinning of the membrane lining the lungs.

Intermittent exposure of rats to 4 ppm for a year caused no discernible permanent damage to the lungs (Dreisbach, 1987).

Animals exposed to 70 ppm for 8 hours developed periorbital oedema and corneal opacities (Ellenhorn and Barceloux, 1988).

7.2.3 Relevant in vitro data

No data available.

7.2.4 Workplace standards

Nitrogen dioxide:
Threshold limit value (time weighted average): 3 ppm (6 mg/m^3)

Threshold limit value - STEL: 5 ppm (10 mg/m^3)

NIOSH recommends 1 ppm of nitrogen dioxide as a workplace environmental standard (NIOSH, 1976).

Nitric oxide:
Threshold limit value: 25 ppm

7.2.5 Acceptable daily intake (ADI) and other guideline levels

Not relevant.

7.3 Carcinogenicity

Unknown

7.4 Teratogenicity

Unknown

7.5 Mutagenicity

Unknown

7.6 Interactions

Unknown

8. TOXICOLOGICAL ANALYSES AND BIOMEDICAL INVESTIGATIONS

8.1 Material sampling plan

8.1.1 Sampling and specimen collection

8.1.1.1 Toxicological analyses

8.1.1.2 Biomedical analyses

8.1.1.3 Arterial blood gas analysis

8.1.1.4 Haematological analyses

8.1.1.5 Other (unspecified) analyses

8.1.2 Storage of laboratory samples and specimens

8.1.2.1 Toxicological analyses

8.1.2.2 Biomedical analyses

8.1.2.3 Arterial blood gas analysis

8.1.2.4 Haematological analyses

8.1.2.5 Other (unspecified) analyses

8.1.3 Transport of laboratory samples and specimens

8.1.3.1 Toxicological analyses

8.1.3.2 Biomedical analyses

8.1.3.3 Arterial blood gas analysis

8.1.3.4 Haematological analyses

8.1.3.5 Other (unspecified) analyses

8.2 Toxicological Analyses and Their Interpretation

8.2.1 Tests on toxic ingredient(s) of material

8.2.1.1 Simple Qualitative Test(s)

8.2.1.2 Advanced Qualitative Confirmation Test(s)

8.2.1.3 Simple Quantitative Method(s)

8.2.1.4 Advanced Quantitative Method(s)

8.2.2 Tests for biological specimens

8.2.2.1 Simple Qualitative Test(s)

8.2.2.2 Advanced Qualitative Confirmation Test(s)

8.2.2.3 Simple Quantitative Method(s)

8.2.2.4 Advanced Quantitative Method(s)

8.2.2.5 Other Dedicated Method(s)

8.2.3 Interpretation of toxicological analyses

8.3 Biomedical investigations and their interpretation

8.3.1 Biochemical analysis

8.3.1.1 Blood, plasma or serum

8.3.1.2 Urine

8.3.1.3 Other fluids

8.3.2 Arterial blood gas analyses

8.3.3 Haematological analyses

8.3.4 Interpretation of biomedical investigations

8.4 Other biomedical (diagnostic) investigations and their interpretation

8.5 Overall Interpretation of all toxicological analyses and toxicological investigations

Sample collection
Collect blood samples to assess arterial blood gases and methaemoglobin levels.

Biomedical analysis
Arterial blood gas studies show hypoxia, hypercapnia and acidosis with early changes in the alveolar - arterial oxygen gradient.

Pulmonary function tests show obstructive, restrictive and diffusion defects as a result of destruction of alveoli, interstitium and bronchioles (Ellenhorn & Barceloux, 1988).

8.6 References

9. CLINICAL EFFECTS

9.1 Acute poisoning

9.1.1 Ingestion

Unknown

9.1.2 Inhalation

The irritant effects of oxides of nitrogen cause inflammation of the lungs, leading to profuse exudation into the alveolar spaces. Pulmonary oedema, rapid breathing and cyanosis are early features.

Relapse may occur after 2 to 3 weeks with the onset of bronchiolitis obliterans.

Chest X-ray shows fluffy confluent bilateral infiltrates in patients with pulmonary oedema, and a

nodular pattern in cases of bronchiolitis obliterans.

9.1.3 Skin exposure

Skin burns can occur when nitrous fumes mix with sweat to form nitric acid.

9.1.4 Eye contact

Exposure to nitrogen oxides can cause conjunctivitis.

9.1.5 Parenteral exposure

Not relevant.

9.1.6 Other

Not relevant.

9.2 Chronic poisoning

9.2.1 Ingestion

Unknown.

9.2.2 Inhalation

No adverse effects were found in workers exposed for several years at 30 to 35 ppm oxides of nitrogen (ACGIH, 1986).

9.2.3 Skin exposure

No data available.

9.2.4 Eye contact

No data available.

9.2.5 Parenteral exposure

Unknown.

9.2.6 Other

Unknown.

9.3 Course, prognosis, cause of death

Clinical features depend on the duration and intensity of exposure and follow a triphasic pattern.

Initially, there is mild irritation of the upper respiratory tract.

Mild cases become asymptomatic within several hours. The severity of initial symptoms does not correlate well with subsequent pulmonary pathology, although patients with mild nitrogen dioxide exposure often recover without any late complications.

After a latent period of 32 hours (in some instances lasting up to 72 hours) patients may develop inflammation of the lungs and pulmonary oedema.

About 50% patients surviving pulmonary oedema develop bronchiolitis obliterans in 2 to 6 weeks.

In a few instances, bronchiolitis obliterans may be the initial presentation with symptoms including progressive dyspnoea, cyanosis, cough and wheezing.

The patient may be even more intensely ill during this relapse than during the initial reaction.

Recovery can take up to 6 months. Emphysematous change persists, depending on the severity of the original damage.

Death can occur due to asphyxia within a few hours of the onset of pulmonary oedema.

Exposure to high concentrations in the region of 100 to 500 ppm may leads to sudden death from bronchospasm and respiratory failure. Delayed pulmonary oedema can cause death. Several weeks after exposure, bronchiolitis obliterans can cause death.

9.4 Systematic description of clinical effects

9.4.1 Cardiovascular

Rapid and weak pulse, cyanosis, venous congestion and hypotension occur secondary to anoxia and haemoconcentration (Gosselin et al. 1984). Hypotension may occur due to a direct effect of nitrates on blood vessels (Haddad and Winchester, 1990).

9.4.2 Respiratory

Usually no symptoms occur at the time of exposure with the exception of a slight cough and perhaps fatigue and nausea. Exposure to low concentrations may result in impaired pulmonary defence mechanisms (macrophages, cilia) with complications.

Only relatively high concentrations of nitrogen oxides produce prompt coughing, choking, production of mucoid and frothy sputum, headache, nausea, abdominal pain and dyspnoea and tightness and burning pain in the chest. There may be haemoptysis.

Inhalation of nitrogen dioxide for a short period causes increased airways resistance (Horvath, 1980). This seems to be due to histamine release (Guidotti, 1978).

A symptom-free period may follow exposure and lasts for 5 to 72 hours. Fatigue, uneasiness, restlessness, cough, tachypnoea and dyspnoea, appear insidiously as adult respiratory distress syndrome gradually develops.

Increasingly rapid and shallow respiration, cyanosis, coughing with frothy expectoration, and physical signs of bronchospasm and pulmonary oedema such as crackles and wheezes can be observed. Vital capacity is rapidly reduced. A serous exudate may develop in the pleural cavity, but its volume is usually small. Anxiety, mental confusion, lethargy, and finally loss of consciousness occur as a result of hypoxia.

Chest X-ray may show widespread, coarse mottling throughout the lung fields. Lungs may be radiologically clear within a few days, in parallel with clinical improvement (Milne, 1969). Circulatory collapse is secondary to anoxia and haemoconcentration.

Death may occur within a few hours of the first evidence of pulmonary oedema.

Sometimes a second acute phase follows the initial pulmonary reaction after a quiescent period of 2 to 6 weeks. Cough, tachypnoea, dyspnoea, fever, tachycardia and cyanosis at this stage are usually due to bronchiolar inflammation which may lead to bronchiolitis obliterans (Milne, 1969).The relapse may be abrupt and fulminating, leading either to death or a slow convalescence.

Chest X-ray reveals widespread bilateral mottling.

Blood gas analysis indicates hypoxia.

In non-fatal cases, convalescence may be complicated by infection, bronchitis, bronchiolitis obliterans, pneumonia and general weakness. Rarely, diffuse pulmonary fibrosis may develop.

9.4.3 Neurological

9.4.3.1 Central Nervous System (CNS)

The effects are secondary to hypoxia. There may be confusion.

9.4.3.2 Peripheral nervous system

Not known

9.4.3.3 Autonomic nervous system

Not known

9.4.3.4 Skeletal and smooth muscle

Not known

9.4.4 Gastrointestinal

There may be nausea.

9.4.5 Hepatic

Not known

9.4.6 Urinary

9.4.6.1 Renal

Unknown

9.4.6.2 Others

Unknown

9.4.7 Endocrine and reproductive systems

Unknown

9.4.8 Dermatological

Skin burns from nitric acid may occur due to the mixture of fumes with sweat (Haddad and Winchester, 1990).

9.4.9 Eye, ears, nose, throat: local effects

There may be conjunctivitis and sore throat.

9.4.10 Haematological

Severe haemoconcentration occurs due to the fluid loss in pulmonary oedema. Leucocytosis can occur even in the acute initial phase (Haddad and Winchester, 1990).

Changes in blood chemistry (such as decreased red cell membrane acetylcholinesterase activity, red cell glucose-6-phosphate dehydrogenase, total haemoglobin and haematocrit and an increase in red cell peroxidized lipids) have been seen in young adults exposed to nitrogen dioxide 1 or 2 ppm for 3 hours daily for 3 days (Gosselin et al., 1984).

Methaemoglobinaemia has been reported (Haddad and Winchester, 1990).

9.4.11 Immunological

Unknown.

9.4.12 Metabolic

9.4.12.1 Acid-base disturbances

Metabolic acidosis can occur due to the formation of nitrous acid and the

development of lactic acidosis (Haddad and Winchester, 1990).

9.4.12.2 Fluid and electrolyte disturbances

Pulmonary inflammation and oedema result in fluid loss from blood.

9.4.12.3 Others

Unknown

9.4.13 Allergic reactions

Unknown

9.4.14 Other clinical effects

Unknown

9.4.15 Special risks

Pregnancy: Unknown.

Breast feeding: Unknown.

Enzyme deficiencies: Unknown.

9.5 Others

American astronauts on the Apollo - Soyuz mission were briefly exposed by accident to nitrogen dioxide. Elevated urinary levels of hydroxylysine glycosides suggested collagen breakdown in the pulmonary parenchyma (Ellenhorn & Barceloux, 1988).

9.6 Summary

10. MANAGEMENT

10.1 General principles

Remove the patient from the source of exposure.
Establish an adequate airway and maintain respiration.
Give oxygen and assisted ventilation if necessary.
Remove secretions.
Advise strict bed rest.
Asymptomatic patients should be kept under observation for up to 72 hours.

10.2 Life supportive procedures and symptomatic treatment

Establish an adequate airway and respiration. Remove frothy exudate from respiratory tract. Give oxygen for dyspnoea and cyanosis. If severe pulmonary oedema is present, assisted ventilation may be needed.

Give normal saline or plasma expanders intravenously or blood transfusion to maintain adequate perfusion pressure.

Do frequent sputum cultures. Treat infection with appropriate

antibiotics.

Correct acid-base abnormalities.

If pulmonary oedema is not present, ensure a urine output of at least 1500 ml daily by giving adequate fluids.

If symptoms of irritation or bronchospasm occur give a bronchodilator such as salbutamol by nebulizer.

Give methylprednisolone 20 to 80 mg orally or intravenously. Repeat daily for 8 weeks before gradually decreasing the dose (Haddad and Winchester, 1990).

10.3 Decontamination

Eye contact:
Irrigate exposed eyes with copious amounts of water.

10.4 Enhanced elimination

Not relevant

10.5 Antidote treatment

10.5.1 Adults

No specific antidote.

10.5.2 Children

No specific antidote.

10.6 Management discussion

For bronchospasm, atropine, epinephrine, expectorants, and sedative drugs are ineffective and harmful (Gosselin et al., 1984).

Patients must be followed-up for at least 6 weeks since relapses can occur.

Asymptomatic patients could be discharged after 24 to 36 hours of observation but they should be followed up within several weeks to assess pulmonary status.

11. ILLUSTRATIVE CASES

11.1 Case reports from literature

Cough, dyspnoea at rest and on exertion, chest pain, headache, haemoptysis and weakness were the symptoms reported by 116 people exposed to fumes from a malfunctioning engine (Hedberg et al., 1989).

A chemist exposed to nitrogen dioxide (nitrous fumes) had cough and slight headache only. Twelve hours later he was awakened with dyspnoea and cough. On admission to hospital soon after, he had severe acute pulmonary oedema. He was discharged on the 7th day. On the 20th day after exposure he was readmitted with dyspnoea, coughing and sweating. He

required intermittent positive pressure ventilation. He was treated with corticosteroids and discharged 28 days later (Milne, 1969).

12. ADDITIONAL INFORMATION

12.1 Specific preventive measures

Exposure to oxides of nitrogen at workplace should be avoided by appropriate storage of chemicals and by following proper safety standards.

12.2 Other

No data available.

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