Information and recommendations for doctors at hospitals/emergency departments

- Patients exposed only to hydrogen sulfide gas do not pose a significant risk of secondary contamination. Patients whose clothing or skin is contaminated with liquid hydrogen sulfide (boiling point –60°C, -76°F, respectively) can secondarily contaminate rescue and medical personnel by direct contact or through off-gassing hydrogen sulfide.

- Hydrogen sulfide gas is irritating when it comes in contact with moist tissue such as the eyes, skin, and upper respiratory tract and causes headache, nausea, vertigo, dizziness, weakness, hypotension, and disorientation. Laryngospasm, signs of pulmonary edema (shortness of breath, cyanosis, expectoration, cough), unconsciousness, and apnea may occur. Rapid onset of unconsciousness, “knock-down”, of severely exposed individuals is characteristic.

- In case of suspected hydrogen sulfide poisoning immediate ventilation and oxygenation is crucial. Use of cyanide antidotes may be effective in severe cases when given immediately after exposure, but may be hazardous after onset of pulmonary edema.

1. Substance information
   Hydrogen sulfide (H2S), CAS 7783-06-4
   Synonyms: dihydrogen monosulfide, sewer gas
   Hydrogen sulfide is, at room temperature, a colorless, flammable gas with a rotten-egg odor. Under pressure or at temperatures below –60°C (-76°F), it is a clear, colorless liquid. It is moderately water-soluble.
   Hydrogen sulfide is used or encountered in farming (usually as agricultural disinfectant), brewing, tanning, glue making, rubber vulcanizing, metal recovery processes, mineral oil and gas exploration and processing, in rayon or artificial silk manufacture, lithography and photoengraving, fur-dressing and felt-making plants, fertilizer cookers, beet sugar factories, analytical chemistry, and dye production.

2. Routes of exposure

   Inhalation
   Most exposures occur by inhalation. Hydrogen sulfide’s odor and irritant properties may be well perceived; however, they do not provide warning of hazardous concentrations. Moderate levels of exposure result in olfactory loss. Hydrogen sulfide is heavier than air and may cause asphyxiation in poorly ventilated, low-lying, or enclosed spaces.

   Skin/eye contact
   Direct contact with liquid hydrogen sulfide or gas on wet or moist skin or mucous membranes of the eyes causes irritation.

   Ingestion
   Ingestion of hydrogen sulfide is unlikely because it is a gas at room temperature.

3. Acute health effects

   Respiratory
   Hydrogen sulfide exposure usually causes headache, nausea, vertigo, dizziness, weakness, disorientation, hypotension, and respiratory irritation. Pulmonary injury may progress over several hours. Severe hydrogen sulfide poisoning may cause unconsciousness, respiratory and cardiovascular failure. Rapid onset of unconsciousness followed by immediate recovery, “knock-down”, of severely exposed individuals is characteristic. Reawakening patients may experience an acute brain syndrome with agitation and confusion.
Dermal
If skin is wet or moist, contact with hydrogen sulfide gas can cause irritation. Contact with liquid hydrogen sulfide under pressure can result in frostbite.

Ocular
Exposure to low concentrations of hydrogen sulfide gas causes burning discomfort, spasmodic blinking or involuntary closing of the eyelids, redness, and tearing. Corneal opacities may occur at high concentrations or repetitive exposure.

Estimation of exposure
If monitoring data or other measurements are available, inhalation exposure can be estimated.

Dose-effect relationships
Dose-effect relationships are as follows:

<table>
<thead>
<tr>
<th>Hydrogen sulfide concentration</th>
<th>Effect</th>
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<tbody>
<tr>
<td>0.02-0.2 ppm</td>
<td>Odor detection (some tolerance develops)</td>
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<tr>
<td>50-150 ppm</td>
<td>Eye and respiratory irritation, olfactory paralysis</td>
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<tr>
<td>200-500 ppm</td>
<td>Bronchitis, headache, dizziness, staggering</td>
</tr>
<tr>
<td>500-1000 ppm</td>
<td>Pulmonary edema, respiratory depression, unconsciousness</td>
</tr>
<tr>
<td>1000-1500 ppm</td>
<td>Rapid collapse, respiratory paralysis, fatal within a few minutes</td>
</tr>
<tr>
<td>1800-5000 ppm</td>
<td>Immediately fatal</td>
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</table>

Potential sequelae
If the patient survives the initial 48 hours after exposure, recovery is likely. After acute exposure, pulmonary function usually returns to normal in 7 to 14 days. Complete recovery is usual; however, symptoms and pulmonary deficits may persist. Airways hyperreactivity to non-specific irritants may persist, resulting in bronchospasm and chronic inflammation of the bronchi; reactive airways dysfunction syndrome has been reported to persist for years. Sequelae of the pulmonary tissue destruction and scarring may lead to chronic dilation of the bronchi and increased susceptibility to infection. Neurologic sequelae may occur as a result of respiratory insufficiency.

4. Actions

Self-protection
Patients exposed only to hydrogen sulfide gas do not pose a significant risk of secondary contamination. Patients whose clothing or skin is contaminated with liquid hydrogen sulfide can secondarily contaminate other people by direct contact or through off-gassing hydrogen sulfide.

Decontamination
Patients exposed only to hydrogen sulfide gas who have no evidence of skin or eye irritation do not need decontamination. All others require decontamination.

Assure that exposed or irritated eyes have been irrigated with plain water or saline for at least 20 minutes. If not, continue eye irrigation during other basic care. Remove contact lenses if present and easily removable without additional trauma to the eye.

Assure that exposed skin and hair have been flushed with plain water for at least 15 minutes. If not, continue flushing during other basic care. Protect eyes during flushing of skin and hair.

Initial treatment
In cases of suspected hydrogen sulfide poisoning, immediate ventilation and administration of humidified 100% oxygen is crucial. In all unconscious patients immediate endotracheal intubation, if necessary under sedation with benzodiazepine and morphine derivatives, is recommended. Mechanical ventilation with a FiO₂ of 1.0 (100% of oxygen) should be started, regardless of the blood gas analysis.

Very high PaO₂ such as at 200 mmHg can be tolerated for several hours. The administration of oxygen can be considered as antidotal treatment.
Immediate and very early administration of cyanide antidotes (but NOT sodium thiosulfate) may be beneficial in preventing severe anoxia, but may be hazardous after onset of pulmonary edema because oxygen transport is decreased in methemoglobinemia (see Antidotes below). The following measures are recommended if exposure is 50-150 ppm (depending on time exposed), if symptoms, e. g. eye irritation or pulmonary symptoms have developed, or if the exposure concentration can not be estimated but exposure has possibly occurred:

If not already done, initially, administration of 8 puffs of beclomethasone (800 µg beclomethasone dipropionate) from a metered dose inhaler.

Thereafter, administration of 4 puffs every 2 hours for 24 hours.

At an exposure concentration of 200-300 ppm (depending on time exposed), establishment of intravenous access and intravenous administration of 1.0 g methylprednisolone (or an equivalent steroid dose), should be considered, if not already done.

Note: Efficacy of corticosteroid administration has not yet been proven in controlled clinical studies.

Intubation of the trachea or an alternative airway management should be considered in cases of respiratory compromise. When the patient’s condition precludes this, consider cricothyrotomy if equipped and trained to do so.

If hydrogen sulfide gas or hydrogen sulfide generating solutions have been in contact with the skin, chemical burns may result; treat as thermal burns. If liquefied compressed gas is released and contacts the skin, frostbite may result.

After eye exposure chemical burns may result; treat as thermal burns. Immediately consult an ophthalmologist.

Note: Any facial exposure to liquid hydrogen sulfide should be considered as a serious exposure.

The following treatment with antidotes should be given under medical supervision to unconscious patients who have known or suspected hydrogen sulfide poisoning. Immediate and very early administration of cyanide antidotes (but NOT sodium thiosulfate) may be beneficial in preventing severe anoxia, but may be hazardous after onset of pulmonary edema because oxygen transport is decreased in methemoglobinemia. The effectiveness is not proven by clinical trials. The availability of antidotes may vary due to statutory and regulatory differences among different countries.

Note: In some countries administration of 0.2-0.4 ml amyl nitrite via Ambu bag is recommended before the following treatment. If amyl nitrite is to be used, one ampoule should be administered for 30 seconds every minute until intravenous access is established for further treatment; it should be omitted until good oxygenation is present and there are not signs of pulmonary disturbance.

If 4-dimethylaminophenol (4-DMAP) is available, the following method of treatment may be considered: Administer immediately 4-DMAP intravenously, usually in a dose of 3 to 5 mg/kg body weight (i.e. 1 ampoule of 250 mg 4-DMAP in an adult). If 4-DMAP is not available, infuse sodium nitrite intravenously as soon as possible. The usual adult dose is 10 to 20 ml of a 3% solution infused over 5 minutes. Monitor blood pressure during sodium nitrite administration, and slow the rate of infusion if hypotension develops.

CAUTION! Sodium thiosulfate must not be administered in case of hydrogen sulfide poisoning.

Do not treat methemoglobinemia, unless 4-DMAP was overdosed or the initial diagnosis of hydrogen sulfide poisoning is revised.

Please note that conscious patients should neither receive 4-DMAP nor sodium nitrite.
After treatment with 4-DMAP or sodium nitrite, blood methemoglobin levels should be monitored and should not exceed 30 to 40 %, given anemia is not present. Cyanosis occurs with methemoglobin concentrations of approximately 15 %. In cases of overdosage, treat the methemoglobinemia.

**Whenever infusions of 4-DMAP or sodium nitrite have been used, the patient should be admitted to the intensive care unit.**

**Laboratory tests**

The diagnosis of acute hydrogen sulfide toxicity is primarily a clinical one, based on the irritation of respiratory tract and the presence of rapid “knock-down” and known or strongly suspected hydrogen sulfide exposure. After treatment with 4-DMAP or sodium nitrite, blood methemoglobin levels should be monitored.

**Further evaluation and treatment**

To the standard intake history, physical examination, and vital signs add pulse oximetry monitoring and a PA chest X-ray.

Spirometry should be performed. Routine laboratory studies should include a complete blood count, blood glucose and electrolyte determinations. Arterial blood gases and methemoglobin concentration should be performed to assess for the presence of acidosis and methemoglobinemia in symptomatic patients. In individuals with neurologic findings, a CT head scan should be performed to assess the presence of brain lesions.

**Evidence of pulmonary edema** - hilar enlargement and ill-defined, central-patch infiltrates on chest radiography - is a late finding that may occur 6 to 8 hours or later after exposure. The chest X-ray is typically normal on first presentation to the emergency department even with severe exposures.

Patients who have possible exposure or who develop serious signs or symptoms should be observed for a minimum of 24 hours and reexamined frequently before confirming the absence of toxic effects. Delayed effects are unlikely in patients who have minor upper respiratory symptoms (mild burning or a slight cough) that resolve quickly.

If oxygen saturation is less than 93 % or if it appears to drop, immediately check arterial blood gasses and repeat the chest X-ray. If blood gasses begin to show deterioration and/or if the chest X-ray begins to show pulmonary edema start additional oxygen supplementation.

Should it become clear that pulmonary edema is worsening, positive end-expiratory pressure (PEEP) therapy should be started within the first 24 hours after exposure even if oxygenation can be maintained by mask. **Early indication for PEEP therapy is tachypnea (>30/min) with a simultaneous decrease of the partial pressure of carbon dioxide.** An inadequate increase or a relative decrease of the partial pressure of oxygen despite hyperventilation indicates the development of pulmonary edema.

Hyperbaric oxygen may be given to those patients who continue to be symptomatic after standard therapy.

Fluid intake/output and electrolytes should be monitored closely. Avoid net positive fluid balance. Central line or Swan-Ganz catheterization might be considered, to optimize fluid management.

As long as signs of pulmonary edema are present, intravenous administration of 1 g methylprednisolone (or an equivalent steroid dose) should be continued in intervals of 8-12 hours.

Patients with bronchospasm should be treated as follows:

a) Aerosolized β₂-selective adrenergic agonist, e.g. 4 puffs of terbutaline, or salbutamol, or fenoterol from a metered dose inhaler (1 puff usually contains 0.25 mg terbutaline sulfate, or 0.1 mg salbutamol, or 0.2 mg fenoterol, respectively); may be repeated once after 10 min.
If inhalation is not possible, terbutaline sulfate (0.25-0.5 mg) subcutaneously or salbutamol (0.2-0.4 mg over 15 min) intravenously.

b) If a) is not effective or insufficient: theophylline (5 mg/kg body weight intravenously over 20-30 min).

c) If a) and b) are not effective or insufficient: 2 puffs of epinephrine (0.4 mg per puff) from a metered dose inhaler; may be repeated after 5 min. Prophylactic antibiotics are not routinely recommended, but may be used based on the results of sputum cultures. Pneumonia can complicate severe pulmonary edema.

In reawakening patients with an acute brain syndrome with agitation and confusion sedation may be necessary.

Patient release/ follow-up instructions

Asymptomatic patients exposed to a concentration of less than 50 ppm (depending on the period of time exposed) and have a normal examination and no signs or symptoms of toxicity after observation for 12 hours may be discharged in the following circumstances:

a) The evaluating physician is experienced in the evaluation of individuals with hydrogen sulfide exposure.

b) Information and recommendations for patients with follow-up instructions are provided verbally and in writing. Patients are advised to seek medical care promptly if symptoms develop or recur.

c) The physician is comfortable that the patient understands the health effects of hydrogen sulfide.

d) Site medical is notified, so that the patient may be contacted at regular intervals in the 24-hour period following release from the emergency department.

e) Heavy physical work should be precluded for 24 hours.

f) Exposure to cigarette smoke should be avoided for 72 hours; the smoke may worsen the condition of the lungs.

Patients who have serious skin or eye injuries should be reexamined in 24 hours.

Post discharge spirometry should be repeated until values return to the patient’s baseline values.

In this document BASF has made a diligent effort to ensure the accuracy and currency of the information presented but makes no claim that the document comprehensively addresses all possible situations related to this topic. This document is intended as an additional resource for doctors at hospitals/emergency departments in assessing the condition and managing the treatment of patients exposed to hydrogen sulfide. It is not, however, a substitute for the professional judgement of a doctor and must be interpreted in the light of specific information regarding the patient available to such a doctor and in conjunction with other sources of authority.