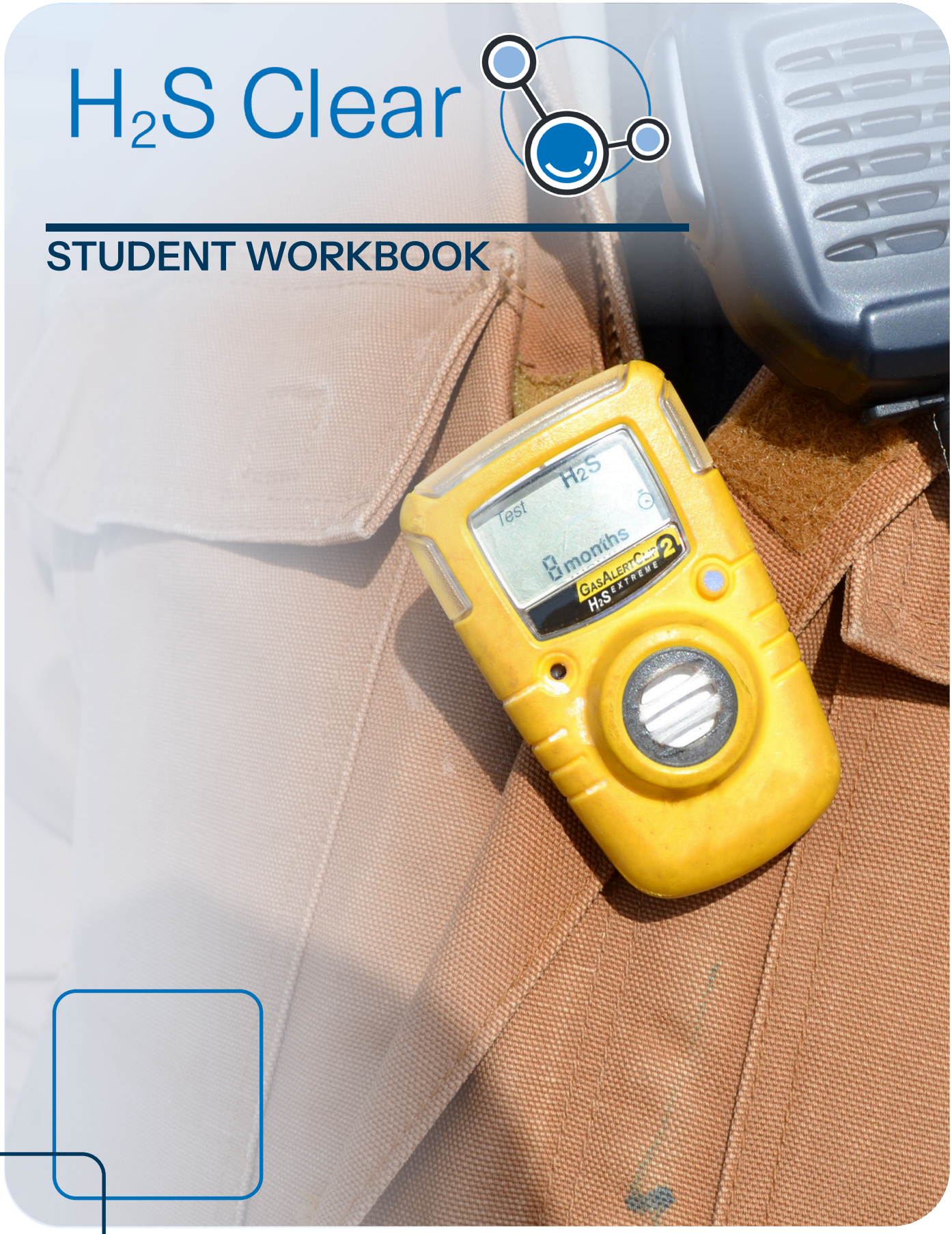
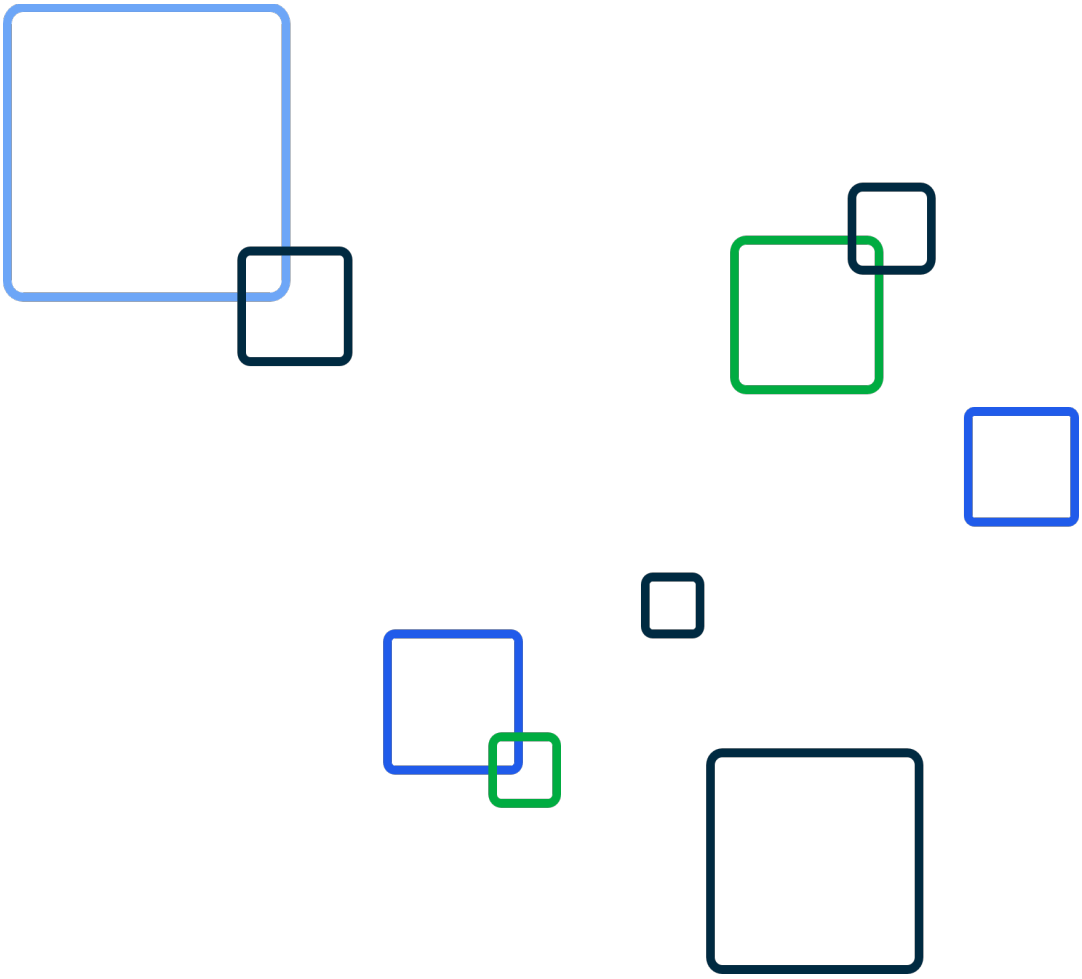
H_2S Clear

STUDENT WORKBOOK



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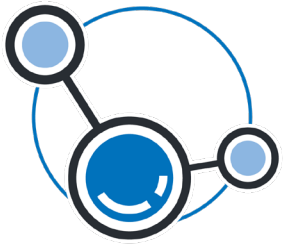
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Title: H2S Clear Student Workbook
Published by: Veriforce

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H_2S Clear



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Section 1: Industry Overview

CONSTRUCTION CASE STUDY

Answer the following questions for class discussion.

1. **What could have prevented this incident from happening?**

2. **Who was responsible for the incident?**

RESPONSIBILITIES ACTIVITY

RESPONSIBILTY	Company	Worker
Attend annual H_2S education and training sessions.		●
Implement a respiratory protection program.	●	●
Monitor H_2S levels throughout the workplace.	●	●
Use required PPE and personal monitors.	●	●
Provide PPE specifically designed to shield individuals from effects of H_2S.	●	●
Establish safe work practices related to H_2S.	●	●
Use SWA when necessary.	●	●
Report exposure incidents.	●	●
Follow safe work practices.	●	●
Provide site-specific training for individual facilities.	●	●

Each topic in this course includes a fill-in-the-blank exercise to help you identify important information. Follow along as your instructor covers each topic and fill in your answers as you go.

FILL-IN-THE-BLANK: SECTION 1

1. **The responsibility of establishing safe work practices relating to H_2S falls on the _____.**
2. **You and your coworkers are responsible for reporting exposure incidents, attending H_2S education and training sessions, and using required _____ and personal _____.**

Notes

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Section 2: Introduction to Hydrogen Sulfide

SOURCES OF HYDROGEN SULFIDE ACROSS INDUSTRIES	
Industry	**Potential Exposure**
Agriculture	▪ Manure and other organic matter decomposition ▪ Manure processing buildings ▪ Cleaning manure storage tanks or working in manure pits
Animal Production and Rendering	▪ Decomposing matter, such as blood, fat, and other animal parts, during some work activities
Construction	▪ Released during excavation work in swamps or old landfills
Ironworking	▪ Iron smelters ▪ Coke ovens
Mining	▪ Mines and tunnels ▪ Mineral rock ▪ Surface and groundwater from mining and processing operations ▪ Under conditions frequently found in natural waters, especially groundwater, sulfate can be reduced by naturally occurring sulfate-reducing bacteria, creating H_2S
Oil and Gas Processes	▪ Upstream » Oil and natural gas wells » Water injection and enhanced recovery operations ▪ Midstream » Natural gas underground storage fields (salt caverns and formations) » Pipelines transporting products that contain or may contain H_2S » Transporting materials containing H_2S by highway or rail ▪ Downstream » Byproducts of H_2S can be used to convert into elemental sulfur or sulfuric acid, also known as battery acid » Used to create a variety of inorganic sulfides used to create pesticides, leather, dyes, and pharmaceuticals » H_2S scavengers in hydrocarbon processing facilities
Power	▪ Coal-fired plants during line-break activities ▪ Producing heavy water for nuclear power plants
Pulp and Paper Manufacturing	▪ By-product of wood breaking down into pulp
Sanitation	▪ Cleaning or maintaining municipal sewers and septic tanks
Treatment	▪ Sewers, sewage treatment plants, manure tanks, and other places where organic material breaks down without oxygen
Wind Energy	▪ Sub-structures of offshore wind turbines
All industries	▪ Enclosed facilities or piping that contains H_2S gas or H_2S-contaminated fluids

PHYSICAL AND CHEMICAL PROPERTIES OF HYDROGEN SULFIDE		
Property	**Characteristic**	**Hazards**
Toxicity	▪ Highly toxic	▪ Causes severe health effects if inhaled
Density	▪ Density: 1.5g/L ▪ Vapor density: 1.19 at 32°F at 760 mmHg ▪ 19% heavier than air	▪ Collects in low-lying areas and confined spaces
Flammability	▪ Flammable limit: 4.3% – 46% vapor by volume in air	▪ Extremely flammable ▪ May spontaneously ignite at high temperatures
Melting Point	▪ Melting point: -117.2°F (very low) ▪ Can be compressed into a liquid and transported by sea, highway, rail, air, or pipeline	▪ H_2S is almost always in gas form, meaning it will be invisible to you ▪ If in compressed liquid gas form, can cause frostbite upon contact
Combustibility	▪ Auto-ignition temperature: 500°F ▪ Flashpoint: -76.4°F (extremely low)	▪ Quite explosive ▪ Transported containers of compressed H_2S may explode if exposed to fire or handled carelessly
Reactivity	▪ Reacts with strong oxidizers (e.g., bleach, hydrogen peroxide) to cause fire, explosions, or metal damage ▪ Reacts with many metals (e.g., iron, steel) ▪ Can dissolve in water and oil	▪ Produces toxic sulfur dioxide (SO_2) gas when burned ▪ Forms metal sulfides that spontaneously ignite when exposed to air ▪ Severely corrosive to metals, such as steel, carbon steel, copper, silver, brass, and bronze ▪ Solubility decreases as the temperature of the liquid rises

FILL-IN-THE-BLANK: SECTION 2

1. **In every industry, enclosed facilities or piping can contain _____ gas.**
2. **H_2S may spontaneously _____ at high temperatures.**
3. **H_2S is extremely explosive because it has such a low _____.**
4. **Because H_2S is heavier than air in the atmosphere, it collects in _____ areas.**
5. **H_2S leads to failures, ruptures, and sulfide stress cracking because it causes severe _____ to metals.**

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Section 3: Effects of Hydrogen Sulfide

PARTS PER MILLION AS PERCENTAGES	
Parts per million	**Percentages**
1,000,000	100%
100,000	10%
10,000	1%
1,000	0.1%
100	0.01%
10	0.001%
1	0.0001%

HYDROGEN SULFIDE WORKPLACE EXPOSURE LIMITS	
Organization	**Exposure Limit**
OSHA	Acceptable ceiling concentration (ACC): 20 ppm
NIOSH (followed by API and ANSI)	Recommended exposure limit (REL): 10 ppm Immediately dangerous to life or health (IDLH): 100 ppm
ACGIH	Threshold limit value (TLV) – time-weighted average (TWA): 1 ppm Short term exposure limit (STEL): 5 ppm

Notes

ACTIVITY: HEALTH EFFECTS OF EXPOSURE

Parts per million	Effects
1	
10	
20	
50	
100	
200	
500	
700	
1,000	

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SYMPTOMS OF HYDROGEN SULFIDE EXPOSURE	
Acute Toxicity	**Chronic Toxicity**
▪ Olfactory paralysis ▪ Excitement (anxiety) ▪ Eye irritation ▪ Coughing ▪ Headaches ▪ Sneezing ▪ Nausea ▪ Respiratory tract irritation ▪ Diarrhea ▪ Dizziness ▪ Confusion ▪ Staggering gait ▪ Sensitivity to light ▪ Pulmonary edema (chemical pneumonia) ▪ Brain damage ▪ Respiratory arrest ▪ Cardiac arrest	▪ Low blood pressure ▪ Eye irritation ▪ Headaches ▪ Nausea ▪ Respiratory tract irritation ▪ Loss of appetite (seen as “anorexia” on SDS) ▪ Weight loss ▪ Chronic cough ▪ Psychological disorders ▪ Sleep disturbances ▪ Corneal blistering, pitting, and opacity ▪ Pulmonary edema (chemical pneumonia)

FILL-IN-THE-BLANK: SECTION 3

1. **The exposure that poses the greatest danger to workers is _____, which can lead to death.**
2. **A single breath of H_2S at about 1,000 ppm can paralyze your respiratory system and result in convulsions, coma, and _____.**
3. **If you are unsure of the concentrations of toxic, corrosive, or asphyxiant substances in an area, you should consider it _____.**

Section 4: Controlling the Hazards

SULFUR DIOXIDE	
Concentration in Air (ppm)	**Exposure Limits and Typical Characteristics**
0.25	▪ ACGIH STEL
1	▪ Burned match odor ▪ May cause respiratory changes
2	▪ NIOSH REL ▪ API action level
5	▪ Burning eyes, breathing irritation, and minor throat irritation ▪ OSHA PEL ▪ NIOSH STEL
12	▪ Throat-irritating cough ▪ Constriction in chest ▪ Watering eyes ▪ Nausea
100	▪ IDLH
150	▪ Extreme irritation ▪ Can be tolerated for only a few minutes
500	▪ Causes a sense of suffocation, even with the first breath ▪ Rescue promptly and apply artificial ventilation and CPR techniques
1,000	▪ Death may result unless rescued right away ▪ Immediately start artificial breathing and CPR

FILL-IN-THE-BLANK: SECTION 4

1. **Engineering controls are the preferred method after elimination/substitution because they _____ workers from H_2S.**
2. **When H_2S burns, it forms another toxic gas called _____.**

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Section 5: Reducing the Hazards

API HYDROGEN SULFIDE CONDITIONS				
API Condition	**Suspected H_2S Concentration**	**Requirements**	**Minimum Necessary Special Safety Equipment**	**Assigned Flag**
No Hazard Condition	Negligible or no amount of H_2S	▪ No special equipment required	▪ None	None
API Condition I – Low Hazard	Less than 10 ppm	▪ Safety equipment readily accessible	▪ Oxygen resuscitator ▪ H_2S detector	Green
API Condition II – Medium Hazard	10 – 30 ppm	▪ Audible and visual alarms in place ▪ Safety equipment readily accessible	▪ Oxygen resuscitator ▪ H_2S monitor	Yellow
API Condition III – High Hazard	Greater than 30 ppm	▪ Warning signs posted within 500 ft. of area at all entrances in addition to signs at entrances to space ▪ Safety equipment readily accessible ▪ Inspect all H_2S safety equipment before entering ▪ Emergency procedures and emergency contacts in place ▪ At least 2 exits available ▪ No untrained workers allowed in area	▪ One metered H_2S monitor ▪ One pump H_2S monitor ▪ Respiratory protection ▪ Oxygen resuscitator ▪ Three wind socks or streamers ▪ Two NIOSH approved 30-minute escape pack SCBAs	Red

TYPICAL ALARM SETTINGS			
	Alarm Level	**H_2S Concentration**	**Warning Signal**
On Land	Low alarm	10 ppm	Flashing amber light
	High alarm	20 ppm	Intermittent siren
Offshore	Low alarm	10 ppm	Flashing amber light
	High alarm	20 ppm	Intermittent siren and flashing red light
	Very high alarm	50 ppm	Continuous siren and flashing amber and red light

CONFINED SPACE SAFETY MEASURES

Using the necessary safety measures for H2S in confined space work will help keep you and your coworkers safe from the hazardous effects of the gas.

These measures include:

- Obtaining a confined space permit that relates to H2S exposure conditions (include the GPS location on the permit, if applicable)
- Maintaining compliance with permit requirements
- Conducting air monitoring before entering any confined space that may contain H2S
- Ventilating the work area, vents, and purge lines before entering
- Conducting continuous monitoring while workers are in the confined space
- Venting or purging lines on vessels before beginning work
- Being aware of emergency rescue procedures if there is an overexposure to H2S
- Obtaining any necessary training for procedures relating to H2S and confined spaces

Make sure that all required permits are used and that compliance is maintained with the requirements of the permit.

Never take shortcuts, and always follow all procedures.

ORGANIC WASTE FACILITY CASE STUDY

Answer the following question for class discussion.

1. **What could have prevented this incident from happening?**

_____

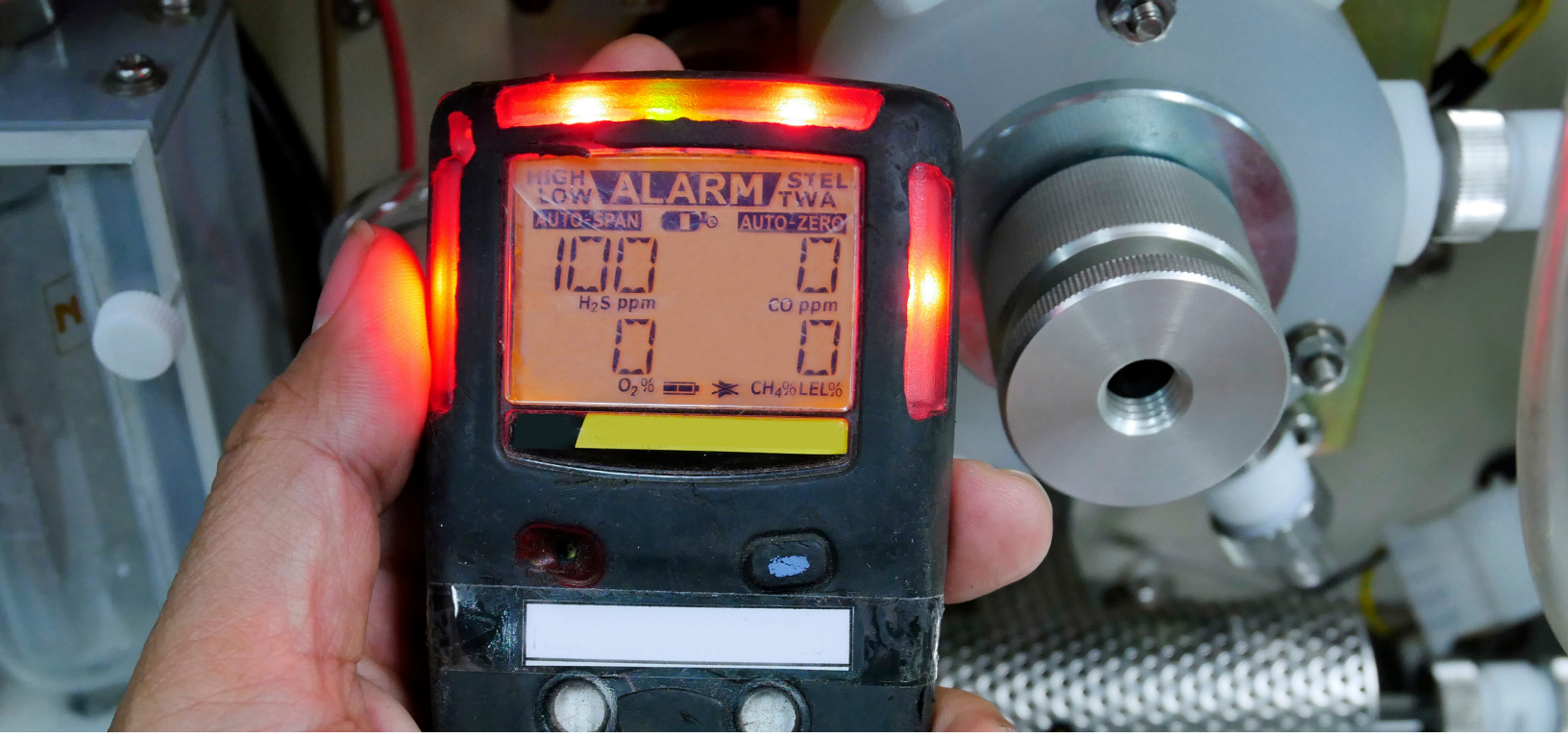
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SECTION 5: FILL-IN-THE-BLANK

1. **Tools used in areas that H_2S might be present should be _____.**
2. **When you see flashing lights or hear alarms, stop breathing and leave the area _____ unless you are trained and authorized to deal with an H_2S emergency.**
3. **Make sure you are not _____ of an H_2S source.**
4. **When in an IDLH area, you should always use the _____ system.**

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Section 6: Protecting Workers: Detection and Monitoring

HYDROGEN SULFIDE CONCENTRATIONS WITH NOTICEABLE ODORS	
H_2S Concentration (ppm)	Odor
0.13	Minimal perceptible odor
0.77	Faint but perceptible odor
4.6	Easily detectible, moderate odor
27	Strong, unpleasant odor
28-100	Rotten egg odor or sweet, acetone-like odor

AGHORN (CSB VIDEO) CASE STUDY

Answer the following question for class discussion.

1. **What could have prevented this incident from happening?**

MONITORING FOR POTENTIALLY HAZARDOUS ATMOSPHERES	
Atmospheric Condition	Acceptable Entry
Oxygen	19.5% to 23.5%
LEL (combustible gas)	0% to 10% (many companies only allow 0%)
Carbon monoxide	0 ppm to 25 ppm
H_2S	0 ppm to 10 ppm

PERFORMING A BUMP TEST

1. **Make sure you have an approved calibration gas cylinder.**
2. **Turn the gas detector or monitor on using the normal startup procedure.**
3. **Attach the proper flow-per-minute regulator to the cylinder.**
4. **Attach the tubing to the calibration fitting for your gas detector or monitor.**
5. **Open the regulator to apply calibration gas to the gas detector or monitor.**

SECTION 6: FILL-IN-THE-BLANK

1. Fixed devices that send warnings in the form of an alarm to warn people in the area to leave are known as gas _____.
2. Portable devices that clip onto workers' uniforms that are used to detect the presence of gas are known as gas _____.
3. Workers must wear personal monitors near their neck and face as close to their mouth and nose as possible to measure air from the _____ zone.
4. When testing the atmosphere of a confined space, take readings from various _____.
5. Before each use, you need to perform a(n) _____ test on your gas monitor.
6. Gas detectors must be serviced and tested according to the _____ recommendations.

Section 7: Protecting Workers: Respiratory Protection

SECTION 7: FILL-IN-THE-BLANK

1. Your company must have written standard operating procedures for respiratory protection in the form of a _____.
2. To determine if a respirator fits you properly, you must be _____ before you can use one.
3. Respirators only work if they properly _____ to your face.
4. Situations consisting of unknown hazards must be considered _____ environments.
5. Workers must use positive-pressure respiratory protection in IDLH conditions, such as a full-face _____.

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Section 8: Emergency Response

FIRST AID FOR VICTIMS OF HYDROGEN SULFIDE	
Inhalation exposure	▪ Get medical attention immediately. ▪ If a person breathes in large amounts of H_2S, move that person to fresh air immediately, if you are trained to rescue. ▪ If the victim is not breathing, perform rescue breathing, preferably with a one-way valve. ▪ Keep the affected person warm and at rest.
Skin exposure	▪ If liquid H_2S gets on the skin, immediately flush the contaminated skin with water. ▪ If liquid H_2S goes through your clothes, remove the clothes immediately and flush the skin with water.
Eye exposure	▪ Flush your eyes immediately with large amounts of water, lifting the upper and lower lids occasionally. ▪ If your eyes still feel irritated after washing, get medical attention.

SECTION 8: FILL-IN-THE-BLANK

1. **Only rescue an H_2S victim if you are _____.**
2. **Unfortunately, an H_2S emergency may leave a _____ behind.**
3. **Victims of H_2S inhalation should be transported to a health care facility to receive professional medical attention and remain under observation until _____ by a licensed health care professional.**

Section 9: Emerging Technology

SECTION 9: FILL-IN-THE-BLANK

1. **New technology can improve safety when working around H_2S, but only if workers are trained to use it _____.**

Glossary

Acute toxicity – adverse health effects that happen after a single exposure to a substance, or multiple exposures within a short period of time

Administrative controls – work practices used to reduce worker exposure that cannot be controlled using engineering controls

Air monitoring – assessing what hazards are in the air and how concentrated they are

Air-purifying respirator (APR) – has an air-purifying filter, cartridge, or canister that removes specific air contaminants by passing air through an air purifier

Alarm system – provides an early warning signal; required at your workplace and should be seen and heard throughout the workplace

Assigned protection factor (APF) – a number that stands for the level of protection a properly functioning respirator would be expected to provide to properly fitted and trained users

Audible alarms – devices that can be distinguished above and apart from the normal sound level in the workplace

Auto-ignition temperature – the lowest temperature at which a substance will spontaneously ignite

Bag valve mask – a type of oxygen resuscitation equipment used to give breathing air to fallen workers in an emergency

Breathing zone – the area just in front of the face and shoulders; a hemisphere with a 6-9 in. radius that centers on your nose

Buddy system – a safe work practice that pairs workers together so that if one buddy needs help, their buddy can assist them or call for help

Bump test – exposing a gas monitor to a defined concentration of gases to make sure its alarms and sensors are working properly

Burning and flaring – controlled burning of a high vapor pressure liquid or compressed gas in order to reduce or control the pressure and/or dispose of the product

Calibration – exposing gas monitor sensors to known concentrations of different calibration gases to make sure a gas monitor's readings are accurate

Cascade system – a system of breathing air cylinders designed to provide breathing air to hoseline respirators

Chronic toxicity – adverse effects that happen after continuous or repeated exposure to a toxic substance

Compressor – a machine that is part of the system used to provide breathing air to a hoseline supplied-air respirator

Confined space – a space that is large enough for a worker to enter, has limited or restricted entry or exit, and is not meant to be occupied for a long amount of time

Contingency plan – a company document that gives workers a step-by-step guide for dealing with emergencies

Corrosion – metal degradation caused by hazardous chemicals

Crosswind – moving at a right angle to the current wind direction

Density – a measurement of how heavy a substance is when compared to normal air at an equal temperature and atmospheric pressure

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Dispersion model – a model used for predicting conditions that can happen as a result of a release of hydrogen sulfide; can be included as part of a company's contingency plan

Downwind – working where the wind could blow hydrogen sulfide in your direction

Emergency Response Guidebook – details how emergency responders should act during the initial phase of a dangerous goods or hazardous materials transportation incident; issued by the United States Department of Transportation

Engineering controls – reduce sources of exposure through jobsite design and modification

Escape pack – a self-contained breathing apparatus respirator used for short-term emergency use; also known as an emergency-use respirator, escape-only respirator, or an auxiliary self-contained breathing apparatus

Fit test – a test that makes sure a respirator is completely sealed with no leaks that would let contaminants in

Fixed detector – a device that continuously monitors hydrogen sulfide concentrations in a specific location

Hazardous atmosphere – areas where there are contaminants in excess of the permissible exposure limit or threshold limit value-time-weighted average

Hoseline respirator – a supplied-air respirator that gets breathing air from a cascade system or compressor from an attached hose; also known as an airline respirator

Hydrogen sulfide (H_2S) – toxic gas that is colorless and collects in low-lying areas and confined spaces

Immediate action plan – a plan that describes what to do as soon as you are aware of an emergency situation

Immediately dangerous to life or health (IDLH) – an environment that causes negative health effects that cannot be reversed and reduces your ability to escape from a dangerous atmosphere

Job safety analysis (JSA) – formal review of a jobsite for hazards that is completed before work begins

Kick – also known as a burp; an entry of water, gas, oil, or other formation fluid into the wellbore during drilling or work over that occurs because the pressure exerted by the column of fluid in the wellbore is not great enough to overcome the pressure exerted by the fluids in the formation drilled

Maximum use concentration (MUC) – the maximum atmospheric concentration of a hazardous substance a worker can be expected to be protected from when wearing a respirator that is determined using a respirator's assigned protection factor and a hazardous substance's exposure limit

Metal sulfide – a product formed by a reaction between hydrogen sulfide and a metal, such as iron or steel, which could auto-ignite and burn when exposed to air

Naturally occurring radioactive material (NORM) – made up of materials enriched with radioactive elements found in the environment

Negative-pressure seal check – a way to check a respirator's integrity by closing off the inlet opening to see if any air leaks into the respirator

Oxidizer – a chemical other than a blasting agent or explosive that initiates or promotes combustion in other materials, causing fire either by itself or through the release of oxygen or other gases

Oxygen deficiency – when there is less than 19.5% oxygen in the air

Oxygen resuscitation equipment – used to give breathing air to fallen workers in an emergency

Parts per million (ppm) – a measurement that means parts of a vapor or gas per million parts of air, by volume

Personal monitor – a device workers wear within the breathing zone that measures hydrogen sulfide concentrations in the surrounding air

Portable monitor – a device designed to be placed between a worker and the source of hydrogen sulfide or in a confined space; used to measure the amount of hydrogen sulfide in the atmosphere

Positive-pressure seal check – a way to check a respirator's integrity by closing off the exhalation valve to see if any air leaks out of the respirator

Qualitative fit test (QLFT) – an exam that relies on your response to a test agent to determine if a respirator is completely sealed

Quantitative fit test (QNFT) – an exam that measures how much a respirator leaks

Regulator – a device used to control the rate of gas released from the calibration gas cylinder during portable monitor (gas monitor) calibration

Respirator – a device that covers your mouth and nose and is designed to improve the air your lungs breathe in

Safety data sheet (SDS) – gives detailed information about the hazards of a specific material and how to control those hazards

Self-contained breathing apparatus (SCBA) – a supplied-air respirator where the breathing air source is designed to be carried by the user

Service life – how long respiratory equipment provides workers with enough protection

Shelter-in-place – staying indoors until an emergency is over rather than trying to evacuate

Soluble – a substance's ability to dissolve in other liquids, particularly water

Sour – term commonly used to refer to environments or fluids (such as crude oil) that contain hydrogen sulfide

Sour environments – fluids that contain water and hydrogen sulfide

Spontaneous – describes something that happens without warning

Standby worker – A worker who is required to be outside an immediately dangerous to life or health area while workers are inside; must maintain communication with the workers inside and may be trained and equipped to rescue workers inside or be available to notify a rescue team if needed

Stop work authority (SWA) – your right to stop work when you or your coworkers are at risk because of the way a job is being done

Sulfide stress cracking – cracks in susceptible metals caused by corrosive hydrogen sulfide

Sulfur dioxide (SO_2) – very irritating, toxic, and colorless gas that has a strong, nasty odor

Supplied-air respirator (SAR) – type of respirator that supplies clean air to the user from some other source

Upwind – working in an area away from the way the wind is blowing the source of hydrogen sulfide; moving opposite the direction the wind is blowing

Ventilation – a method of controlling the environment with air flow; an engineering control used to improve or maintain the quality of air in a work environment

Visual alarms – the use of steady, flashing, or strobe lights to alert workers to an emergency situation in areas with high noise levels

Wind sock – a device used to check which way the wind is blowing

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Acronyms and Abbreviations

ACC	Acceptable ceiling concentration
ACGIH	American Conference of Governmental Industrial Hygienists
ANSI	American National Standards Institute
APF	Assigned protection factor
API	American Petroleum Institute
APR	Air-purifying respirator
BSEE	Bureau of Safety and Environmental Enforcement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CO	Carbon monoxide
CO_2	Carbon dioxide
CPR	Cardiopulmonary resuscitation
DOT	Department of Transportation
EMS	Emergency medical services
EPA	Environmental Protection Agency
ERG	Emergency Response Guidebook
g/L	Grams per liter
GHS	Globally Harmonized System
H_2S	Hydrogen sulfide
IDLH	Immediately dangerous to life or health
JSA	Job safety analysis
L	Liter
LEL	Lower explosive limit
mL	Milliliter
MUC	Maximum use concentration
NFPA	National Fire Protection Agency
NIOSH	National Institute for Occupational Safety and Health
NORM	Naturally occurring radioactive material
O_2	Oxygen
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PAPR	Powered air-purifying respirator
PEL	Permissible exposure limit
PLHCP	Physician or other licensed health care provider
PPE	Personal protective equipment
ppm	Parts per million
QLFT	Qualitative fit test
QNFT	Quantitative fit test
REL	Recommended exposure limit
RP	Recommended practice
RQ	Reportable quantity
SAR	Supplied-air respirator
SARA	Superfund Amendments and Reauthorization Act
SCBA	Self-contained breathing apparatus
SDS	Safety Data Sheet
SO_2	Sulfur dioxide
STEL	Short-term exposure limit
SWA	Stop work authority
TLV	Threshold limit value
TWA	Time-weighted average
UN ID	United Nations Identification Number
USCG	United States Coast Guard
WHMIS	Workplace Hazardous Materials Information System