

SECTION II
HEALTH AND SAFETY MANUAL
FOR
FIELD ACTIVITIES

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INTRODUCTION

The Basic Health and Safety section of this course has been developed using many materials on occupational safety and health that are part of the training for inspectors from the United States Environmental Protection Agency (EPA). Their training is designed to protect inspectors from many of the same hazards that you too will face. By following the practices detailed herein, you can help ensure your own health and safety and ultimately that of your family members as well.

In some places in your manual you will see references to standards or rules set by U.S. agencies such as the Occupational Safety and Health Administration (OSHA) or the National Institute for Occupational Safety and Health (NIOSH). The standards that these agencies establish for individuals who come in contact with hazardous materials, or who work under hazardous conditions, are based upon the best scientific estimates of conditions that are acceptable to maintain the good health of workers. You may see reference, for example, to Permissible Exposure Limits (PELs); it is believed that most people who are exposed to the PEL of a harmful substance during the course of an eight-hour work day will not experience any harmful effect from such exposure. Exceeding a PEL puts you at an increased risk to the toxic effects of hazardous materials.

You will also see references to rating standards for protective equipment or monitoring instruments. In the United States an independent group called Underwriters Laboratory (UL)

examines and rates electrical equipment (including monitoring equipment) for safe use under different conditions. Inspectors are advised to look for these rating systems to help them evaluate whether or not equipment is safe to use under the expected work conditions. For instance, a monitoring device that is not spark proof may pose a severe risk if it is used in an environment that has sufficient concentrations of explosive vapors or dust.

Additional information pertaining to health and safety issues can be obtained from your instructors and the reference materials listed in this manual.

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OPENING STATEMENT

BASIC HEALTH AND SAFETY MANUAL FOR FIELD PERSONNEL

Field inspections involve a certain degree of risk. Inspections of wastewater treatment plants, manufacturing plants, laboratories and mines are each associated with various hazards. A safe

field inspection depends on the recognition, evaluation and control of hazards. During field activities, it is not always possible to eliminate hazards. However, it is possible to reduce the risk associated with these hazards, through the use of monitoring or testing equipment, engineering controls, personal protective equipment and employee training.

This course manual is an introduction to the basic health and safety training required for conducting field activities. The goal of this manual is to provide you with the information necessary to make the correct health and safety decisions in the field. This manual examines health and safety principles and identifies methods to recognize and evaluate the hazards associated with field activities.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
ANSI	American National Standards Institute
CFR	Code of Federal Regulations
CPR	Cardiopulmonary Resuscitation
CHRIS	Chemical Hazard Response Information System
EPA	Environmental Protection Agency
IDLH	Immediately Dangerous to Life or Health
LEL	Lower Explosive Limit
MSHA	Mine Safety and Health Administration

NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PAPR	Powered Air-Purifying Respirator
PEL	Permissible Exposure Limit
PPE	Personal Protection Equipment
REL	Recommended Exposure Limit
SAR	Supplied-Air Respirator
SCBA	Self-Contained Breathing Apparatus
TLV	Threshold Limit Value
TWA	Time Weighted Average
UEL	Upper Explosive Limit
USCG	U.S. Coast Guard

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1.1 OBJECTIVE

To identify key elements that must be considered when preparing for field activities.

1.2 INTRODUCTION

Importance of Preplanning

- Field personnel encounter a wide variety of potential hazards.
- Preplanning can reduce or eliminate many hazards.

Planning Process

- Research potential hazards.
- Evaluate the risks.
- Select appropriate protective equipment and clothing.

Sources of Information

- Plant personnel
- Agency files
- Agency employees
- Industry standard references

1.3 PRE-FIELD ACTIVITY EVALUATION

Planning Guide

- Prepare planning guide. (See Appendix 1-A).
- Acquire pertinent medical records and other information.
- Take guide and information to the site.
- Leave a copy with your supervisor.

Components of the Planning Guide

- Activity location

- name and address
- contact name and telephone number
- photographs
- Historical information
- Activity schedule
- Inspection personnel
 - names
 - restrictions
 - required training
- Lodging
- Hazards
 - transportation (distances, chemicals, supplies, test equipment, etc.)
 - noise
 - fire/explosion
 - biological
 - weather-related
 - chemicals
 - atmospheric
 - thermal
 - radiological
 - confined space
 - drowning
 - physical and mechanical (height, machinery, etc.)
- Vehicles
- Required permits
- Emergency and rescue
 - communication (telephone, two-way radio, etc.)
 - warning signals (fire, evacuation, severe weather, etc.)
 - hospitals, emergency assistance personnel
- Personal protective equipment and clothing
- Miscellaneous

1.4 ONSITE EVALUATION

- Request a health and safety briefing.
- Conduct a walk-through survey.
 - hidden hazards
 - natural hazards
- Record unexpected hazards, additional gear requirements.

APPENDIX 1-A

SAMPLE SAFETY AND HEALTH PLANNING GUIDELINE FOR FIELD ACTIVITIES

Facility/Site:

Location:

Agency files exist ___ Yes ___ No

If yes, list pertinent historical information

DATES AND LENGTH OF PROPOSED ACTIVITY:

SITE CONTACTS:

Name	Position	Tel. Number
------	----------	-------------

INSPECTION TEAM:

Name	Medical monitoring	Field training	Respiratory training	Medical/Physical restrictions
------	-----------------------	-------------------	-------------------------	----------------------------------

LODGING ARRANGEMENTS: Motel/Hotel

Location _____ Telephone _____

SITE ACCESS REQUIREMENTS:

Identification

Permits

Visitor's agreement

Special problems

Type of communication needed

VEHICLE(S) AND EQUIPMENT:

Motor Vehicles

Make

License Plate

Mobile laboratory

Other (list)

Vehicle safety check made? ☐ yes ☐ no

Boat/Airplane will be used? ☐ yes ☐ no

List vehicle to be used

Boat/plane safety check made? ☐ yes ☐ no

ANTICIPATED HAZARDS TO CONSIDER:

Driving distance

Biological hazards

Hauling reagents

Radiological hazards

Hauling test equipment

Noise

Moving hazards

Heights

Thermal hazards

Confined space

Chemical hazards

Weather

Flammable hazards

Terrain

TOXIC SUBSTANCES (LIST):

HAZARD MONITORING EQUIPMENT:

EMERGENCY SIGNALS AND COMMUNICATION:

Fire signal is

Evacuation signal is

Severe weather signal is

Toxic release signal is

EMERGENCY AND RESCUE:

Is first aid available in the area? ___ yes ___ no

Location

Telephone #

Is ambulance available? _____ on site

on call Tel. #

Nearest hospital with emergency services:

Location

Telephone #

Heavy and special rescue services/equipment available: ___ yes ___ no

Specify:

PERSONAL PROTECTIVE EQUIPMENT/CLOTHING: (Check if needed)

Eyes and Head

Safety glasses

Type

Face shield

Goggles

Hard hat

Type

Hearing protection

Type

Other

Body, Hands, Feet

Coveralls

Type

Foul weather gear

Fully encapsulating gear

Safety footwear

Type

Boot/shoe covers

Gloves

Type

Other special equipment/clothing

Respiratory Protection

Air-Purifying Respirator

Type

Cartridge, Filters

Type

SCBA	Type
Emergency Escape Mask	Type
Airtank Full ___ yes ___ no	

Special Health and Safety Equipment

Life belt
Safety line
Other

Decontamination Supplies

Waste bags and ties
Cleaning solution
Disposable brushes
Disposable towels and towelettes
Disposable containment tubs

MISCELLANEOUS

Rope	String	Tape
Matches	Food	Potable Water
Additional Clothing		

NOTE: A copy of this summary should be taken along for reference in the event of an emergency. A second copy should be filed with a supervisor before leaving for the site. Such information is particularly important for visits to sites where crews may be stranded or lost.

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CHAPTER 2

2.0 HAZARDS, EXPOSURE AND EVALUATION

2.1 OBJECTIVE

To provide information regarding general safety considerations, how exposures to hazardous chemicals may occur, how to assess these hazards, and how to protect oneself and others.

2.2 INTRODUCTION

- Inspectors will encounter a variety of physical, biological, and chemical hazards during inspections.

- Exposure to chemicals is the most common and significant health hazard field personnel encounter.
- Chemicals may be hazardous because they are toxic, flammable, combustible, explosive, corrosive, reactive, radioactive, biologically active, or some combination of these and other characteristics.
- Inspectors should learn basic first aid techniques.

2.3 SAFETY GUIDELINES AND TECHNIQUES

- Lifting and carrying
- Ladders and climbing
- Power sources and electrical equipment
- Confined spaces
- Mechanical hazards
- Biological hazards
- Show video

Lifting and Carrying

- Assess the following:
 - overall weight
 - distribution of weight
 - security of contents
 - distance
 - obstacles
 - surface conditions
 - visibility
- Use two people.
- Lift with power of leg muscles.
- Do not climb ladder with heavy load.

Ladders and Climbing

Portable Ladders

- Inspect ladders for hazards.
- Position ladder base 1/4 of working length from wall.
- Use only ladders with non-skid feet; be sure ladder rests on non-slip level surface.
- Wear appropriate clothing.
- Do not use:
 - step ladders >6 m (20')
 - straight ladders >9 m (30')
 - two-section extension ladders >15 m (48')
 - three-section extension ladders >18 m (60')
- Face ladder when climbing and descending.
- Have someone stabilize bottom.

- Do not hand carry anything up the ladder.
- Prevent tools and equipment from catching on ladder or falling.
- Do not use ladder as scaffold or bridge.
- Do not permit more than one person on ladder.
- Do not reposition ladder while on it.

Fixed Ladders

- Minimum design load: 91 kg (200 lbs)
- Evenly spaced stepping surface 30 cm (12")
- Adequate clearance
- Minimum 18 cm (7") clearance behind each rung
- Safety devices or cages: >6 m (20')
- Pitch: 75°-90°

Working Surfaces

- Check integrity of elevated platforms before climbing up to them.
- Discontinue inspection if personal safety is jeopardized.

Power Sources/

Electrical Equipment

- Shut off power where possible.
- Remove highly conductive equipment if power cannot be shut off.
- Wear protective gear - hard hats, gloves, etc.

Electrical cords/plugs

- Inspect periodically and repair.
- Use three-wire equipment.
- Ensure continuity of grounding wire.
- Ensure diameter of wires is sufficient to prevent loss of voltage or overheating.

Uninsulated Electrical

Conductors or

Metal Parts

- Ensure exposed metal parts of electrical equipment are grounded.
- Use a Ground Fault Circuit Interrupter (GFCI) in the line.
- Use double-insulated power tools.

Static Electricity

- Sources include:
 - particulates in process stream
 - electrostatic precipitators
 - lightning
- Safety precautions:
 - ground sampling probes
 - be aware of weather conditions discontinue sampling where lightning hazard exists
 - use A.M. radio for weather reports/static interference

Mechanical Hazards

- Remotely controlled vehicles

- Forklifts
- Potential entanglements

Biological Hazards

Entering certain locations can be hazardous due to the presence of various biological hazards.

Ticks

- Live in areas with tall grasses, bushes.
- Burrow into skin and suck blood.
- Transmit Rocky Mountain Spotted Fever, Lyme's Disease.
- Wear light-colored clothing; tuck pant legs into socks.
- Examine body for presence of ticks.
- Seek medical help if fever, rash or bull's eye pattern develops.

Snakes

- Learn to recognize poisonous varieties.
- Wear knee-high, thick, leather boots and leather gloves.
- Be aware of their habits.
- Bring snake bite kit.
- To treat snake bite:
 - keep victim calm
 - slow circulation
 - use snake bite kit
 - get immediate medical help

Spiders

- Learn to recognize dangerous varieties.
- Get medical help for bites as soon as possible.
- Tarantula bites are painful but seldom serious.

Bees/wasps

- Recognize their habitats.
- Carry bee-sting kit if allergic.
- To treat sting:
 - keep victim calm
 - remove stinger
 - cool area with ice
 - administer cardiopulmonary resuscitation (CPR) if necessary
 - seek medical help

Scorpions

- Usually found under other objects.
- Carry anti-sting kit - sting can be fatal to allergic individual.
- Administer CPR if necessary.
- Seek medical help if stung.

Rabid Animals

- Can infect any warm-blooded animal (foxes, dogs, bats, raccoons, skunks, squirrels).
- Animals may exhibit lack of fear, aggressiveness, dropping head, peculiar trotting gait, unusual behavior.
- Seek immediate medical help if bitten by rabid animal; infection nearly 100% fatal if untreated.

Micoorganisms

- Harmful bacteria, viruses and fungi can be found in soil, waste water, medical and pharmaceutical waste.
- Inspectors should avoid direct contact with these materials.

2.4 HEAT STRESS

- Heat production exceeds heat loss.
- Often accompanied by increased:
 - heart rate
 - body temperature
 - respiration
 - perspiration
- Adverse effects range from cramps to death.
- Contributing factors:
 - ambient temperature
 - radiant heat
 - physical labor
 - chemical exposure
 - humidity
 - altitude
 - inadequate acclimatization
 - fatigue
 - alcohol consumption
 - cardiac and respiratory conditions
 - some medications

Preventing/Reducing Heat Stress

- Assess probability of heat stress.
- Schedule work for cool periods of day.
- Take adequate breaks.
- Hoist, rather than carry, heavy loads.
- Use protective heat shields, insulating materials, reflectors, tarpaulins.
- Drink appropriate amounts and types of fluids: 250 ml ($\frac{1}{2}$ cup) water every 15 minutes.
- Wear head coverings and clothing that is:
 - light in color,
 - absorbent, and
 - loose fitting
- Know the symptoms, prevention and treatment of major heat stress disorders.

Heat Stress Disorders

Heat Stroke

- Life-threatening
- Sweating mechanism shuts down; body overheats.

Symptoms

- Red or flushed skin
- Hot, dry skin
- Very high body temperature: 41°C (106°F)
- Dizziness
- Nausea
- Headache
- Rapid, strong pulse
- Unconsciousness

Emergency Treatment

- Cool person rapidly - water, fan, air conditioning.
- Get immediate medical care.
- Allow person to sip water if conscious.

Heat Exhaustion

- If left untreated, may progress to heat stroke.
- Inadequate blood flow and dehydration.

Symptoms

- Pale, clammy skin
- Profuse perspiration
- Extreme fatigue, weakness
- Normal body temperature
- Headache
- Vomiting

Emergency Treatment

- Move victim to cooler location.
- Have person lie down and elevate feet 20-30 cm (8-12").
- Loosen clothing.
- Have person drink electrolyte replacement solution or juice if possible (every 15 minutes for one hour).
- Get medical aid if condition does not improve.

Heat Cramps

- Muscle pains and spasms (abdomen, legs) caused by loss of electrolytes.

Symptoms

- Painful muscle cramping and spasms
- Heavy sweating
- Vomiting
- Convulsions
- Alert, well-oriented, normal pulse and blood pressure

Treatment

- Rest quietly in cool location.
- Loosen clothing.
- Massage cramped muscle.
- Give clear juice or electrolyte replacement solution: 250 ml (½ cup) every 15 minutes for

one hour.

- Get medical help if symptoms not relieved

2.5 FIRE AND EXPLOSION HAZARDS

During your field work you may be exposed to fire and explosion hazards from materials you may be using or encounter.

Recognition of Hazards

Recognizing fire and explosion hazards requires an understanding not only of the types of materials that can catch fire or are reactive with air or water, but also of the processes by which materials burn or explode.

Essential Components

- Combustible material (fuel)
- Oxidizer (oxygen in atmosphere)
- Ignition energy (heat)

Combustible Materials

Those posing greatest concern are dusts, vapors, and gases that can be ignited easily and burn rapidly or explosively;

- **Gases** - diffuse and mix readily with oxygen.
- **Combustible gases** - acetylene, ammonia, butane, hydrogen, methane, propane, etc. - hazard also from containers of combustible gases.
- **Solids** - must be converted to gas or vapor before they will burn. - finely divided may be dangerous (flour, steel wool).
- **Combustible dusts** - agricultural products, wood products, chemicals, pharmaceuticals, metals, and plastics.
- **Liquids** - must be converted to gas or vapor before they will burn. -sprays, mists, foams, or dispersions.
- **Combustible liquids** - liquids capable of being ignited - includes flammable liquids.
- **Flammable liquids** - flash point temperatures below 100°F (38°C) - many industrial chemicals, paints, thinners, solvents, fuels - containers of these are also hazardous. See Table 2-1.

Ignition Energy

- Amount needed depends on:
 - state and concentration of the combustible material; and
 - concentration of oxygen.

- Sources:
 - heated metal
 - sparks
 - flames
 - static electricity and sparks
 - sunlight
 - lasers
 - ionizing radiation
- Ignition temperature
 - Minimum temperature necessary to start the material burning.
 - Varies greatly for different materials.
 - Based on normal concentration of oxygen (21%).

Oxidizer

- Is usually oxygen in air.
- Peroxides, perchlorates, permanganates, sulfuric acid, chlorine and fluorine may act as oxidizers.

Fire and Explosion Characteristics

Many factors contribute to the occurrence of a fire or an explosion.

Flammable Concentration and Flammable Limits

- **Flammable concentration:** all concentrations at which flame will travel through the mixture.
 - **Explosion Limits** - range of concentrations of gases in air which will support the explosive process is bounded by measurable limits called explosive limits. The upper explosive limit (UEL) and the lower explosive limit (LEL) define the parameters of this range. Limits are measured and published as the percentages by volume of vapor or gas in air containing the normal concentration of oxygen. See Table 2-1.
 - **Lower explosive limit (LEL):** minimum flammable concentration of a material - also referred to as the lower flammable limit (too “lean”).
 - **Upper explosive limit (UEL):** maximum flammable concentration of a material - also referred to as the upper explosive limit (too “rich”).

Vapor pressure

- Pressure of the vapor above the surface of the liquid in a container; liquids with high vapor pressures are generally more hazardous than those with low vapor pressures (temperature dependent). See Table 2-1.

Flash point

- Temperature at which a liquid will give off enough vapor to allow flame to propagate through the vapor-air mixture; liquids with low flash points are generally more hazardous. See Table 2-1.

TABLE 2-1. CHARACTERISTICS OF FLAMMABLE LIQUIDS

Liquid	Explosion Limits
--------	------------------

(% in air) (mm Hg at STP)	Vapor Pressure Flash Point (°C)		
Vinyl acetate	2.6 - 13.4	115	-8
Acetone	2.6 - 12.8	227	-18
Ethyl alcohol	3.3 - 19.0	50	13
Methyl ethyl ketone	1.4 - 11.4 (93°C)	71	-9
Gasoline	1.4 - 7.6		-43
Kerosene	0.6 - 5.0		38
Toluene	1.2 - 7.1	30	4
Trichloroethylene	12.5 - 90	77	37
Xylene	1.1 - 7.0	10	29

Specific Gravity

- Most combustible and flammable liquids have specific gravities less than 1.0 - will float on water; water should not be used for firefighting.

- Greater than 1.0 - will sink in water; water can be used for firefighting.

Vapor Density

- If less than 1.0, vapor rises.
- If greater than 1.0, vapor sinks.

Preventing Fire and Explosions

- Keep ignition sources away from flammable concentrations.
- Limit amount of flammable liquids taken on field activities.
- Use available ventilation during transfer of liquids.
- Transport flammable liquids in tightly-sealed containers protected against impact.

Identification of

Hazards

- Get information from Agency files, co-workers who have inspected the site, plant personnel.
- Identify materials which may be present; read reference sources to determine hazards; take appropriate precautions.
- Use direct-reading instruments to detect flammable concentrations onsite.

Control of Ignition Sources

- Be aware of sources: matches, cigarette lighters, electrical switches, electrical equipment, welding sparks, engines.
- All electrical equipment, sampling apparatus, portable instruments, and other possible sources of ignition must be safe for use in atmospheres containing flammable concentrations of dusts, vapors or gases.

Instruments and Equipment

- Most battery-operated or line-powered field instruments are not safe for use in flammable atmospheres.

- If possible, use only equipment approved by Underwriters Laboratory (UL) or Factory Mutual (FM) for use in specific flammable atmospheres.
- Enclose and ventilate sampling equipment which is not approved for use in such atmospheres.
- Be aware that some monitors which check flammable concentrations will give false readings if the concentration is above the upper flammable limit for the material.

Control of Static

Electricity

Since static electricity (which accumulates to higher voltages in atmospheres with low humidity and during dry weather) can provide sufficient ignition energy to set fire to flammable concentrations of gases and vapors, it is important to recognize what can generate static electricity and what can be done to prevent accumulation and discharge of this energy.

Sources

- Particulates moving through a stack.
- Gas issuing from a nozzle at high velocity.
- Pouring or spraying nonconducting liquids or solids.
- Materials flowing through pipes, hoses or ducts.
- Belt running over a pulley.
- Person walking across a floor.
- Pouring solvents.
- Working near a process that generates static electricity.

Preventing Accumulation or Discharge

- Ground probes used for stack sampling.
- Provide a bonding connection between metal containers when flammable gases or liquids are transferred or poured.
- Wear footwear with adequate conductivity for the conditions.

2.6 SELECTION AND USE OF FIRE EXTINGUISHERS

Fire is an oxidation process which requires three key components: fuel, oxygen, heat. Removal of any of these three will stop the oxidation process.

Fire Classification/ Treatment

- See Table 2-2.

Fire Extinguisher Identification

- See Table 2-3.

Firefighting Precautions

- Warn others to evacuate area.
- Call Fire Department.
- Evaluate ability to fight the fire.
 - proper type and size of extinguisher?
 - additional help?
 - obstacles?
 - retreat?

- Contain the fire to prevent spread.
- Fight the fire.
- Never turn your back on the fire.

Using a Fire Extinguisher

- Prepare and test extinguisher before approaching fire.
- Aim at base of fire.

Fire Hose

- Stream reaches about 9 m (30').
- Stand back so pressure does not scatter fire.

Soda-acid

- Turn upside down to mix chemicals and start flow.

Aqueous-charged

- Spread stream into fan-shape with finger if pressure is not too great.

Dry Chemical

- Usually rated “B” and “C”; some are rated “A”, “B”, and “C”.
- Use side-to-side sweeping motion.
 - Cover Class A fire.
 - Start spraying Class B fire at closest edge and continue to far edge; do not get too close.

Liquid CO₂

- Low velocity discharge of CO₂; need to get within 2 to 4 feet of fire.
- Flow of gas generates extreme cold and static electricity.

Foam

- Aqueous foam.
- Effective on Class A or B fires.
- Works well on fairly large fires.

TABLE 2-2. FIRE CLASSIFICATION AND EXTINGUISHING MEDIA

Class	Description	Examples	Extinguishing
Media			
A	ordinary combustibles	wood, paper, cloth, rubber	water, Halon 1211,
baking soda			
B	flammable or combustible liquid or gases		gasoline, fuel oil, kitchen
grease, alcohol, propane		CO ₂ , dry chemicals, foam, Halon 1211, Halon 1301	
C	electrical equipment	electrical equipment	dry chemicals, CO ₂ , Halon
1211, Halon 1301			
D	combustible metals that burn vigorously and react violently with water	Na, K, Mg, Ti, Zr	
	dry powders (graphite, NaCl, other free-flowing noncombustible materials)		

TABLE 2-3. FIRE EXTINGUISHER IDENTIFICATION

Class Type	Symbol Description
A	Burning wastebasket and bonfire

B
C

Container pouring liquid and a fire
Electrical plug and a receptacle with flames

2.7 CHEMICAL HAZARD RECOGNITION AND EVALUATION

- The degree of hazard associated with a particular chemical will depend on its toxicity, the way it is used and the environment in which it is encountered.
- The following factors must be considered in evaluating the degree of hazard present:
 - physical form or classification of the chemical
 - physical and chemical characteristics of the chemical
 - warning properties
 - airborne concentration
 - mode of usage
 - other environmental conditions

Physical Classification

- Solids
- Liquids
- Aerosols
- Gases and vapors

Solids

- Particulates (lead, asbestos)
- Sensitization (Ni)
- Fumes
- Sublimation
- Reactivity

Liquids

- Degree of hazard depends on characteristics of the liquid and how it is used
- Factors influencing hazard include:
 - temperature
 - vapor pressure
 - toxicity
- Types of hazards
 - skin damage
 - direct absorption through skin
 - enhanced absorption of other chemicals
 - splash hazard
 - slipping hazard
 - reactivity

Aerosols

- Aerosols are fine particulates (solid or liquid) suspended in air (dust, fumes, mist, fog, smoke and smog).

- See Table 2-4 for characteristics of air contaminants in work places.
- Results may present inhalation, eye or skin hazards.

Gases and Vapors

- A **gas** is a state of matter in which the material has very low density and viscosity.
- **Vapors** are the evaporation products of chemicals that are normally liquid at room temperature.
- See Table 2-4 for gas/vapor characteristics.
- Gases and vapors may present inhalation, eye and skin hazards.

Physical and Chemical Characteristics

- **Boiling point** - temperature at which liquid changes to a gas.
- **Melting point** - temperature at which a solid changes to a liquid.
- **Vapor pressure** - pressure of vapor immediately above the surface of a material. Term generally applied to liquids; however, solids have vapor pressure as well. Materials with high vapor pressure can create high airborne exposure risks.
- **Solubility** - maximum amount of that substance that will completely dissolve in a given volume of another substance.
- **Flash point** - lowest temperature at which a liquid gives off enough vapor to form an ignitable mixture with air and produce a flame when an ignition source is present. Flashpoint and boiling point are used to determine the classification of flammable liquids.
- **Explosion Limits** - range of concentrations of gases in air which will support the explosive process is bounded by measurable limits called explosive limits. The upper explosive limit (UEL) and the lower explosive limit (LEL) define the parameters of this range. The concentration is generally expressed in percent gas in air.
- **Reactivity** - refers to the likelihood of reacting, rather than the ability to react. Most chemicals will react with some other chemical given the right set of conditions.

Warning Properties

- May include odor, eye, nose or throat irritation and taste.
- To be useful in preventing overexposure, must be evident at a concentration below the permissible exposure limit (PEL).
- Some chemicals have good warning properties (NH_3) while others have none at all (CO).

Odor Threshold

- Odor threshold is airborne concentration at which a chemical can be detected by smell.
- Individuals vary.

- **Useful** odor thresholds are well below the PEL. (NH_3)
- **Useless** odor threshold is well above PEL. (vinyl chloride)
- Olfactory fatigue may influence recognition of hazard. (H_2S)

Eye, Nose and Throat Irritation

- PELs for many chemicals have been based on irritation when it has been demonstrated that toxic effects are produced only by substantially higher concentrations. (HCl)

Taste

- May be useful if a taste is produced at concentrations below the PEL. (saccharin)

Airborne

Concentration

- Since some chemicals do not have adequate warning properties and because individuals vary in their sensitivities to various substances, measurement of airborne concentrations of chemicals may prove to be useful.
- If the potential for chemical exposure is unknown you should not enter the area unless you are properly protected or until the chemicals have been identified and the concentrations reliably measured or estimated.

- If you find yourself in an area where an unknown exposure or spill occurs, or where you begin to experience signs or symptoms of exposure (headache, eye irritation, etc.), leave the area at once.

Chemical Use

- Degree of hazard is significantly influenced by the way a chemical is used.
 - open tanks, hot chemicals, high vapor pressure, poorly designed or malfunctioning ventilation system = high airborne concentration
 - closed system = lower airborne concentrations

Other Environmental Factors

- Temperature.
- Relative humidity.

2.8 EFFECTS OF TOXIC CHEMICALS IN THE BODY

Toxic chemicals can affect the body in different ways, depending on the combination of several factors:

- Route of entry.
- Length of exposure.
- Organs or systems affected.
- Absorption, distribution, storage, and elimination.

TABLE 2-4. CHARACTERISTICS OF AIR CONTAMINANTS IN WORK PLACES

Form	How Generated	Example/Size (micrometers)	Concentration Expressed As
-------------	----------------------	---------------------------------------	---------------------------------------

Aerosols

Dust

From solids by mechanical means:

- grinding
- blasting
- drilling

Quarry dust (less than 1 to 10)

mg/m³⁽¹⁾

Fumes

Condensation products of metals and solid organics, welding on metal

Lead fume (less than 0.001 to 0.1)

mg/m³

Mist

Liquid droplets formed by atomizing liquids or condensing liquids from vapors, entrainment

Chromic acid mist

mg/m³

Smoke

Products of combustion of organic materials

Incinerator (less than 0.5)

mg/m³

Gases and Vapors

Gases

Occupy space of enclosure, liquify only under increased pressure and decreased temperature

CO

H₂S

ppm⁽²⁾

Vapors

Evaporation products of substances normally liquid at room temperature (solvents, gasoline).

Acetone

Carbon disulfide

Benzene

ppm

⁽¹⁾ mg/m³ - milligrams per cubic meter.

⁽²⁾ ppm - parts of gas or vapor per million parts of air.

Routes of Entry

- Chemical substances may enter the body through the skin, respiratory tract and gastrointestinal tract.
- Exposures during field activities are most likely to occur through skin contact or inhalation.

Skin

- Usually effective barrier for protecting underlying body tissues (see Figure 2-1).
- Short exposures to strong concentrations of extremely toxic substances (e.g., organic phosphates, phenol, cyanide) can be serious or fatal.

Potential effects of chemical contact

- No reaction - skin acts as effective barrier
- Skin irritation or destruction of tissue
- Skin sensitization
- Chemical penetrates skin and enters blood stream

Factors influencing effects

- Skin thickness
- Chemical properties
- Skin condition
- Duration of exposure

Figure 2-1. Skin Cross-Section

Respiratory System

- Most common route of entry for gases, vapors and airborne particulates (see Figure 2-2).
- Major factors influencing the toxic effects of airborne chemicals include:
 - concentration in ambient air
 - physical and chemical properties
 - sites of deposition within respiratory system
 - body's ability to counteract effects

Damaging substances

- **Asphyxiants** - gases which can deprive body tissues of oxygen.
 - **simple asphyxiants** - displace oxygen and lead to suffocation (N_2 , He, CH_4 , Ne, Ar)
 - **chemical asphyxiants** - prevent oxygen utilization by chemical interaction (H_2S , CO, HCN)
- **Irritants** - may produce inflammation of the sinuses, throat, bronchi, and alveoli. Cell death may result, leading to edema and secondary infection. May cause increased pulmonary flow resistance. Examples: O_3 , HF, NH_3 , SO_x .
- **Fibrosis producers** - kill normal lung tissue and produce scar tissue which may result in oxygen deprivation. Examples: silicates, asbestos, beryllium.

Figure 2-2. Organs of the human respiratory system

- **Allergens** - substances that act as an antigen upon contact with body tissues (inhalation, ingestion, or skin absorption). Allergens may cause allergic response in the form of bronchoconstriction and pulmonary disease. Examples: isocyanates, sulfur dioxide.
- **Carcinogens** - substances that cause cancerous growth in living tissues, such as the lungs. Examples: coke oven emissions, asbestos, and arsenic.
- **Systemic Toxicants** - substances that enter via the respiratory tract, but affect other parts of the body. Examples: organic solvents, anesthetic gases, lead, and mercury.

Table 2-5 gives a partial list of industrial toxicants that produce respiratory tract disorders.

Gastrointestinal

System

- Chemicals may have a toxic effect on all major and accessory organs (e.g., liver) of the gastrointestinal tract.

Potential means of ingestion

- Mouth pipetting
- Contaminated water or food
- Contaminated smoking materials or cosmetics
- Contaminated hands
- Drinking from contaminated containers

Length of Exposure

Toxic chemicals may affect the body in different ways, depending not only on the route of exposure but also on the length of exposure. Toxic effects may be produced by acute or chronic exposure to chemical agents.

Acute Exposures

and Effects

- Acute, or short-term, exposures to some chemicals can cause:
 - acute effects (sudden onset, short duration)
 - permanent adverse effects
 - delayed effects (temporary or permanent)
 - chronic effects

- You may not be aware of an acute exposure unless there is an immediate reaction (pain, irritation).

Chronic Exposures and Effects

- Repeated or prolonged exposure to low concentrations of some toxic chemicals can cause adverse effects of long duration or frequent reoccurrence.

**TABLE 2-5. INDUSTRIAL TOXICANTS THAT PRODUCE DISEASE
OF THE RESPIRATORY TRACT**

Toxicant

Site of Action

Acute Effect

Chronic Effect

Aluminum

Upper airways

Cough, shortness of breath, irritation

Fibrosis and emphysema

Ammonia

Upper airways

Irritation

Bronchitis, edema

Arsenic

Upper airways

Bronchitis irritation, pharyngitis

Cancer, bronchitis, laryngitis

Asbestos

Lung tissue

Fibrosis, cancer

Beryllium

Alveoli

Edema, Pneumonia

Fibrosis, ulceration

Boron oxide

Alveoli

Edema, hemorrhage

Cadmium oxide

Alveoli

Cough, pneumonia

Emphysema

Carbides of tungsten, titanium, and tantalum

Upper, lower airways

Hyperplasia, metaplasia of bronchial cells

Fibrosis

Chlorine

Upper airways
Cough, irritation, asphyxiant

Chromium VI
Nasopharynx, upper airways
Nasal irritation, bronchitis
Cancer
Cobalt
Lower airways
Asthma
Fibrosis, interstitial pneumonitis
Hydrogen chloride
Upper airways
Irritation, edema

Iron oxides
Alveoli, bronchi
Cough
Benign pneumoconiosis

TABLE 2-5 (continued)

Toxicant
Site of Action
Acute Effect
Chronic Effect
Isocyanates
Lower airways, alveoli
Bronchitis, pulmonary edema, asthma

Manganese
Lower airways alveoli
Pneumonia, often fatal
Recurrent pneumonia
Nickel
Nasal mucosa, bronchi
Irritation
Cancer

Nickel carbonyl
Alveoli
Edema (delayed symptoms)

Nitrogen oxides
 Bronchi, alveoli
 Edema
 Emphysema
 Osmium tetroxide
 Upper airways
 Bronchitis, bronchospasm
 Bronchopneumonia
 Ozone
 Bronchi, alveoli
 Irritation, edema, hemorrhage
 Emphysema, bronchitis
 Phosgene
 Alveoli
 Edema
 Bronchitis, fibrosis, pneumonia
 Phthalic anhydride
 Lower airways, alveoli
 Bronchitis, asthma
 Emphysema
 Sulfur dioxide
 Upper airways
 Bronchoconstriction, cough, tightness in chest
 Bronchitis, nasopharyngitis
 Bronchioles, pleura

 Widespread mottling of x-ray without clinical signs (benign pneumoconiosis)
 Toluene

TABLE 2-5 (continued)

<u>Toxicant</u>	<u>Site of Action</u>	<u>Acute Effect</u>	<u>Chronic Effect</u>
	Upper airways	Bronchitis, edema, bronchospasm	
Vanadium	Upper, lower airways	Irritation, nasal inflammation, edema	Bronchitis
Xylene	Lower airways		

Edema, hemorrhage

Organs and Systems Affected

- Many toxic substances are associated with specific toxic effects on one or more organs or systems, which suggests that there is a selective mode of action for many hazardous substances. While chemical substances may have a broad range of toxic effects on an organism, the effects are sometimes so specific that they are defined in terms of the most susceptible “target cell” or “target organ.”
- Eight other major organs or systems are frequent sites of toxic response to chemical substances (see Table 2-6).

2.9 DOSE-RESPONSE CURVES

A dose-response curve describes the relationship between the absorbed dose (concentration versus time) and the biological response. The threshold limit value (TLV) is that dose below which no significant effect is expected to occur. At higher doses certain effects may be observed which compensate for the toxic effect. At still higher doses, reversible damage to organs may be observed. This damage may become irreversible at sustained or higher levels. As this dose increases to even more toxic levels, death will occur. The shape of the curve will depend on the toxicological properties of the material. See Figures 2-3, 2-4, and 2-5 for representative dose-response curves.

Figure 2-3. Classic Dose-response Curve

Figure 2-4. Dose-response Curve for a Chemical with no TLV

Figure 2-5. Dose-response Curve for a Highly Toxic Chemical

TABLE 2-6 ORGANS/SYSTEMS AFFECTED BY CHEMICAL EXPOSURE

Organs or System	Chemicals Causing Effects
Liver and Bile Ducts (Hepatic System)	Vinyl Chloride, Aromatic Hydrocarbons
Kidney (Renal System)	Heavy Metals, Halogenated Hydrocarbons
Blood and the Blood-forming System (Hematopoietic System)	Benzene, Lead
Heart, Cardiovascular System (CVS)	Carbon Monoxide, Arsine
Neuroendocrine System	DDT

(continued)

TABLE 2-6 (continued)

Organs or System	Chemicals Causing Effects
Immune/Allergy System	Triphenyltin
Central Nervous System (CNS)	Pesticides, Thallium

Types of Effects

Some chemicals do not elicit such dose-response relationships.

Harmful Effects

- Include toxic and lethal effects
- Result from overexposure or overdose
- Three major classes:

- **non-specific corrosive** - irreversible damage to cells and tissues. (strong acids, bases, oxidants)
- **specific toxicological effects** - effects on specific target organs or systems - usually reversible if recognized early. (CCl₄ liver cell damage, HCN asphyxiation)
- **pathological effects** - chronic, usually irreversible. (cancer, mutations, birth defects)

Sensitization Effects

- Not dose-dependent
- Require preconditioning exposure
- Immune system affected
- Allergic and hypersensitivity reactions (Ni, nitrophenols, isocyanates, formaldehyde, etc.)

Factors Influencing Intensity of Toxic Action

Route of Entry

- Intensity and nature of response depends on route of exposure: lead (inhalation vs. ingestion).
- Intensity also related to the acute and chronic toxicity of a substance: hydrogen sulfide.

Age

- Infants, children, adults, and senior citizens differ in their circulatory and excretory systems, musculature and metabolisms which affect the distribution and toxicity of substances: newborns (CNS stimulants/suppressants).

State of Health

- Pre-existing disease may increase sensitivity to toxic agents.
- Nutrition may affect responses.
- Diet can change body composition, physiological and biochemical functioning.

Previous Exposure

- Tolerance
- Increased sensitivity
- No effect

Environmental Factors

- Temperature
- Barometric pressure
- Radiation

Host Factors

- Species
- Sex
- Hereditary factors

2.10 EVALUATING HEALTH HAZARDS AND TOXICITY INFORMATION

Reasons to Seek Information

- Does a hazard exist?
- What degree of risk?
- Is air monitoring needed?

- Can pre-exposure monitoring be done?
- Can personal monitoring be done during the activity?
- Should possible exposures be documented by medical monitoring?
- What specific protective equipment and clothing are necessary?
- How should one use such equipment and clothing?

Exposure Limits

- Limits on skin contact
- Permissible Exposure Limits (PELs)

Skin Contact and

Ingestion Exposure

- Most industrial chemicals required to have precautionary labels.
- Skin and systemic toxicity information provided.

Inhalation Exposure Limits

- **Threshold Limit Values (TLVs)** - reviewed and adopted annually by the American Conference of Governmental Industrial Hygienists (ACGIH) - advisory, but more up-to-date.
- **Permissible Exposure Limits (PELs)** - adopted by the Occupational Safety and Health Administration (OSHA) - mandated.

Categories of Exposure Limits

- **Time-Weighted Average (TWA)** - concentration of a toxic substance to which nearly all workers may be repeatedly exposed without adverse effect - based on eight-hour workday, 40-hour workweek.
- **Short-Term Exposure Limit (STEL)** - 15-minute time-weighted average exposure which shall not be exceeded at any time during a work day.
- **Ceiling (C)** - concentration that should not be exceeded during any part of the working day.

Important Information

- PELs do not represent a fine line between safe and dangerous.
- PELs may not be appropriate for extended shiftwork.
- PELs may not protect all workers.
- PELs are not a relative index of toxicity.
- PELs are based on the best available information.

Signs and Symptoms of Overexposure

Since you may not know the identity of toxic chemicals to which you are being exposed, and many chemicals have inadequate warning properties, you must be aware of signs and symptoms of overexposure.

- **Signs** - observable by others
- **Symptoms** - not observable by others

Signs of Inhalation Exposure

- Sneezing
- Coughing

Symptoms of Inhalation Exposure

- Headache
- Dizziness
- Nausea
- Irritation of eyes, nose, throat

- Increased mucus in nose and throat

Signs of Skin Contact

- Redness
- Swelling
- Dry, whitened skin

Symptoms of Skin Contact

- Irritation
- Itching

Other Signs and Symptoms

- Changes in behavior
- Periods of dizziness
- Muscle spasms
- Irritability

Evaluating Exposure with Instrumentation

Air monitoring instrumentation provides the most reliable means of identifying and quantifying airborne contaminants. Information may be used to help:

- Determine level of worker protection needed;
- Evaluate the level of exposure and, therefore, the health risk to field personnel and the need for medical monitoring;
- Assess potential environmental effects; and
- Provide indicators of the effectiveness of hazard abatement activities.

Appendix 2-A provides detailed information concerning oxygen monitors, combustible gas indicators, and specific chemical monitors.

Preparing for Field

Use of Equipment

Once the appropriate equipment has been selected:

- Read all instructions.
- Practice using the equipment.
- Calibrate the equipment before and after using it.

Characteristics of Air Monitoring Instruments

- Portable.
- Able to generate reliable and useful data.
- Sensitive and selective.
- Inherently safe.

Quantification of Airborne Contaminants

- Direct-reading instruments (See Table 2-7)
 - Flammable or explosive atmospheres
 - Oxygen deficiency
 - Certain gases and vapors

- Ionizing radiation

- Laboratory analysis of air samples
 - Anions
 - Aliphatic amines
 - Asbestos
 - Metals
 - Organics
 - Nitrosamines
 - Particulates
 - PCBs
 - Pesticides

2.11 REFERENCES

Some sources which can provide information concerning the toxicity and other potential hazards of chemicals are listed below.

Airborne Exposure Limit Information

- **Occupational Safety and Health Administration (OSHA)** - Permissible Exposure Limits (PELs) can be found in 29 CFR 1910 Subpart Z.
- **National Institute for Occupational Safety and Health (NIOSH).**
 - Recommended exposure limits (RELs) can be found in criteria documents available from NIOSH, the National Technical Information Service (NTIS), or, in some cases from EPA.
 - **Pocket Guide to Chemical Hazards** - provides useful information on regulated chemicals: PELs, TLVs, RELs and data regarding synonyms, IDLH levels, physical description, chemical and physical properties, incompatibilities, measurement methods, personal protection, respirator selection and health hazards. Single copies available from NIOSH at no charge.
- **American Conference of Governmental Industrial Hygienists (ACGIH)** - Threshold Limit Values (TLVs) are reviewed periodically and the TLV list published annually - available from ACGIH Publications Office, 6500 Glenway Avenue, Building D-7, Cincinnati, OH 45211-4438.

Material Safety Data Sheets

- OSHA Hazard Communication Standard requires all chemical manufacturers and vendors to provide material safety data sheets (MSDSs) for the products that they sell.

- MSDSs contain information concerning:
 - hazardous ingredients
 - physical and chemical characteristics

- acute and chronic health hazards
 - respiratory protection and ventilation requirements
 - fire and reactivity data
 - spill control measures
 - disposal requirements
 - labeling requirements
 - other requirements relevant to the safe use of the product
- Employers are responsible for obtaining or developing an MSDS for each hazardous substance used in their workplaces and ensuring that employees have access to this information.

TABLE 2-7. SOME DIRECT-READING INSTRUMENTS

Instrument

Application

Limitations

Combustible Gas Indicator (CGI)

Measures the concentration of combustible gas or vapor

Accuracy depends, in part, on the difference between the calibration and sampling temperatures. Sensitivity is a function of the differences in the chemical and physical properties between the calibration gas and the gas being sampled. The filament can be damaged by certain compounds such as silicones, halides tetraethyl lead and oxygen-enriched atmospheres. Does not provide a valid reading under oxygen-deficient conditions.

Flame Ionization Detector (FID)

with Gas Chromatography Option

In survey mode, detects the total concentrations of many organic gases and vapors. In gas chromatography (GC) mode, identifies and measures specific compounds. In survey mode, all the organic compounds are ionized and detected at the same time. In GC mode volatile species are separated.

Does not detect inorganic gases and vapors or some synthetics. Sensitivity depends on the compound. Should not be used at temperatures less than 40° F(4°C). Difficult to absolutely identify compounds. High concentrations of contaminants or oxygen-deficient atmospheres require system modification. In survey mode, readings can only be reported relative to the calibration standard used.

Gamma Radiation Survey Instrument

Gamma radiation monitor

Does not measure alpha or beta radiation.

Instrument

Application

Limitations

Portable Infrared (IR) Spectrophotometer

Measures concentration of many gases and vapors in air. Designed to quantify one- or two-component mixtures.

In the field, must make repeated passes to achieve reliable results. Requires 115-volt AC power. Not approved for use in a potentially flammable or explosive atmosphere. Interference by water vapor and carbon dioxide. Certain vapors and high moisture may attack the instrument's optics which must then be replaced.

Ultraviolet (UV) Photoionization Detector (PID)

Detects total concentration of many organic and some inorganic gases and vapors. Some identification of

compounds is possible if more than one probe is used.

Does not detect methane. Does not detect a compound if the probe used has a lower energy level than the compound's ionization potential. Responses may change when gases are mixed. Other voltage sources may interfere with measurements. Readings can only be reported relative to the calibration standard used.

Response is affected by high humidity.

Direct-Reading Colorimetric Indicator Tube

Measures concentrations of specific gases and vapors. Available for a wide variety of chemicals.

The measured concentration of the same compound may vary among different manufacturers' tubes. Many similar chemicals interfere. Greatest sources of error are (1) how the operator judges stain's end-point, and (2) the tube's limited accuracy. Affected by high humidity.

Oxygen Meter

Measures the percentage of O₂ in air.

Must be calibrated prior to use to compensate for altitude and barometric pressure. Certain gases, especially oxidants such as ozone, can affect readings. Carbon dioxide (CO₂) poisons the detector cell.

Source: NIOSH/OSHA/USCG/EPA Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities

Other Sources

- **NIOSH/OSHA Occupational Health Guidelines for Chemical Hazards**, U.S. Government Printing Office, Washington, DC 20402
- **Documentation of the Threshold Limit Values (TLVs)**, ACGIH Publications Office, 6500 Glenway Avenue, Building D-7, Cincinnati, OH 45211
- **CHRIS: Chemical Hazard Response Information System** - available through the National Response Center - Volume 2 - information on hazardous waste spills and dump site cleanup.
- **Fire Prevention Guide on Hazardous Materials**, seventh edition, National Fire Protection Association (NFPA), Quincy, MA 02269 - information on pure chemicals; very little on mixtures.
- **The Merck Index**, 10th edition (1983), Merck and Company, Inc., Rahway, NJ 07065 - information on chemicals, drugs, and biological substances.
- **Dangerous Properties of Industrial Materials**, (current edition), edited by N. Irving Sax, Von Nostrand Reinhold Co., 135 W. 50th Street, New York, NY 10020 - information and technical data on nearly 13,000 industrial and laboratory chemicals.
- **Condensed Chemical Dictionary**, 10th edition (1981), Gessner G. Hawley, Von Nostrand Reinhold Co., 135 W. 50th Street, New York, NY 10020 - concise, descriptive technical data on thousands of chemicals and reactions.
- **Farm Chemicals Handbook**, (1984), Richard T. Meister, editorial director, Meister Publishing Co., 37841 Euclid Avenue, Willoughby, OH 44094 - annual publication listing information regarding pesticides and products.
- **NIOSH Registry of Toxic Effects of Chemical Substances**, (RTECS), 1980 edition, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, NIOSH, Cincinnati, OH 45226, or Government Printing Office, Washington, DC -

contains toxicity data on nearly 40,000 chemicals and lists over 145,000 chemical substances.

- **1984 Emergency Response Guidebook: Guidebook for Hazardous Materials Incidents**, 1984, U.S. Department of Transportation, Materials Transportation Bureau, DMT-11, Washington, DC 20036.
- **Emergency Handling of Hazardous Materials in Surface Transportation**, 1981, Bureau of Explosives, Association of American Railroads, 1920 L Street, NW, Washington, DC 20036.
- **Handbook of Toxic and Hazardous Chemicals**, 1981, Marshall Sittig, Noyes Publications, Noyes Building, Park Ridge, NJ 07656.
- **Toxic and Hazardous Industrial Chemical Safety Manual**, 1982, International Technical Information Institute - available through Laboratory Safety Supply, P.O. Box 1368, Janesville, WI 53547-1368, and others.
- Data bases available to EPA personnel:
 - **OHMTADS: Oil and Hazardous Materials Technical Assistance Data System** (developed by EPA)
 - **HMIS: Hazardous Materials Information System** (developed by DOD, Defense Logistics Agency, Defense General Supply Center, Richmond, VA 23297)
 - **MEDLARS, TOXLINE, TOXBACK, TOXBACK/65**

2.12 EMERGENCY FIRST AID FOR FIELD ACTIVITIES

Since employees engaged in field activities are often in remote, inaccessible areas, it is essential that they know the basics of emergency first aid.

Every field team should have at least one member with current training in first aid, cardiopulmonary resuscitation (CPR) and chemical splash treatment.

Each employee should carry a wallet card with important medical information such as blood type, allergies, current medication and physical impairments.

The following information is very basic and does not take the place of a first aid or CPR course. You should obtain more information on each of the medical emergencies mentioned. The information in this section is derived from two publications: *American Red Cross: Adult CPR* and *American Red Cross: Multimedia Standard First Aid*.

Planning to Provide First Aid or Urgent Care

- Urgent care essential:
 - severe bleeding
 - breathing has stopped
 - no pulse

Preplanning

- Complete a Medical Emergency Planning Checklist:
 - location of nearest medical facility
 - emergency communication and transportation available
 - risks involved in field activities
 - exact location of field activity
 - identification of first aid/urgent care providers in the crew
- Ensure that crew members complete and carry medical information card.
- Gather first aid/urgent care supplies.

Initial Response

- Assess and prioritize treatment (breathing, bleeding).
- Request help or secure transportation for victim.

Providing First Aid or Urgent Care

- Make a prompt rescue.
- Ensure breathing/pulse.
- Control severe bleeding.
- Protect victim from unnecessary manipulation/disturbance.
- Avoid or overcome chilling.
- Determine injuries or cause for sudden illness.
- Examine victim methodically.
- Carry out appropriate first aid.
- Follow specific procedures for the following:
 - obstructed airway
 - adult rescue breathing
 - CPR
 - electrical shock
 - wounds (severe bleeding) and shock
 - specific injuries to head, neck and back-chemical splashes, inhalation of toxic gas and burns
 - drowning
 - heat stress

Obstructed Airway

- Determine whether the person is choking (ask him!).

Conscious Person

- Have another person request medical assistance.
- Perform “Heimlich Maneuver”.
- If you are choking, perform Heimlich Maneuver using fist or back of chair.

Unconscious Person

- Request help.
- Position person on back.
- Open airway.
- Look, listen and feel for breathing.
- Attempt to give two full breaths.

- If unsuccessful, retilt head and try again.
- If still unsuccessful, perform abdominal thrusts and finger sweep to clear obstruction.

Adult Rescue Breathing

- May be required due to:
 - allergic reactions
 - electric shock
 - oxygen-deficient atmosphere
 - toxic gas paralysis
 - obstructed airway
- Check for consciousness, breathing and pulse.

Procedure

- Have someone get medical assistance.
- Position victim onto back.
- Open airway.
- Check again for breathing (listen, watch chest and feel for breath).
- Give two full breaths.
- If still not breathing, reposition head.
- Try again.
- Perform Heimlich Maneuver if airway is blocked.
- Check carotid pulse.
- Begin rescue breathing.
 - one breath every five seconds (approximately 1 to 1½ seconds/breath)
 - listen and feel for breath, watch chest
- Recheck pulse after one minute of rescue breathing.
- Continue rescue breathing until:
 - victim breathes;
 - another rescuer takes over;
 - emergency personnel arrive;
 - you can't continue.

Cardiopulmonary Resuscitation (CPR)

- Chest compressions and rescue breathing used together (15 compressions/two breaths).
- May be needed for:
 - heart attack (most common)
 - electrical shock
 - chemical exposure

- CPR should be administered only by personnel specially trained in the procedure.

Electrical Shock

- Can stop breathing and heart or cause heart to beat ineffectively.
- If victim still in contact with source of electricity:
 - shut off power; or
 - safely move victim away from source.

- Determine need for rescue breathing/CPR.

Wounds (Severe Bleeding and Shock)

- Stop bleeding.
- Protect wounds from contamination.
- Prevent shock.
- Get medical help.

Severe Bleeding

- Direct pressure/elevation.
- Pressure points.
- Tourniquet (sacrifice the limb!)

Shock

- Comfort, quiet, soothe victim.
- Keep victim lying down, normal temperature.
- Standard position - feet and injury elevated.
- If head wound or breathing difficulty, elevate head and shoulders.
- If fractures suspected and not splinted, or elevation is painful, keep victim flat on back.
- Bleeding from mouth, nauseous, vomiting - lie on side.

Head, Neck, Back Injuries

Head, Neck

- Signs of injury:
 - bumps, bruises, cuts
 - headache
 - dizziness
 - unconsciousness
 - unequal pupils
 - sleepiness
 - bleeding/fluid - mouth, nose, ears
 - paralysis
- Sometimes difficult to decide - suspect injury whenever an accident involves force.
- Keep injured head, neck, spine from moving.
- Keep victim lying flat (raise head, shoulders), monitor breathing, get medical help, do not administer stimulants.

Back

- Handle victim carefully.
- Administer rescue breathing without repositioning.

Chemical Splashes

- Flush chemicals off as quickly and thoroughly as possible (15 minutes).

- Splashes of hot, concentrated or corrosive chemicals (several hours).
- Medical followup where indicated.

Eyes

- Irrigate thoroughly (15 minutes).
- Contact lenses may aggravate chemical burns.
- Do not use neutralizing solutions.

Skin

- Remove contaminated clothing.
- Wash affected skin thoroughly.
- Be aware of potential spread of contaminant.
- Try to find water source whose temperature can be adjusted for prolonged washing.
- If victim is conscious, give plenty of non-alcoholic liquids to drink.

Inhalation of Toxic Gas

- Get exposed person out of toxic atmosphere.
- If a toxic liquid has been splashed on victim's face, wash it off quickly.
- Administer rescue breathing.
- Continue until normal breathing is restored or a resuscitator is available.
- Treat for shock.

Burns

- Can be life-threatening depending on location and amount of body affected.
- If burn results from chemical splash, first treat for splash, then burn.
- Stop, drop, roll.
- Major objectives:
 - relieve pain
 - prevent contamination
 - reduce likelihood of shock
- Cooling and aspirin help relieve pain.

Small Shallow Burns

- Use cool water directly on burn on unbroken skin; immerse if possible.
- Pat dry with sterile gauze.
- Bandage if necessary.

Large Shallow Burns

- Cool with water until pain subsides.
- Dry gently and cover with thick, dry, sterile dressing.
- Use insulated cold packs over dressing if helpful.

Deep Burns

- Do not put water on open burn to cool it.
- Cover burn with thick sterile dressing and bandage.
- Do not remove clothing which is sticking to a burn.
- Use dry, insulated cold packs to relieve pain.
- Seek medical assistance for extensive deep burns.

Shock Prevention

- Have victim lie down.
- Elevate burned areas (if possible).
- Maintain normal body temperature.

- Have victim drink water if possible.

Insect Stings and Allergic Reactions

- Ensure adequate airway.
- Remove stinger.
- Use emergency kit.
- Obtain medical attention.

Drowning

- Unless trained in lifesaving, do not attempt personal rescue; use boat, life preserver, etc.
- Begin rescue breathing as soon as possible.
- Use proper technique to move or lift victim with suspected head, neck or back injury.
- Administer rescue breathing and CPR for lengthy time to victim of cold water drowning: <21°C (70°F)
- Victim may vomit.

APPENDIX 2-A

OXYGEN MONITORS, COMBUSTIBLE GAS INDICATORS, AND SPECIFIC CHEMICAL MONITORS

INTRODUCTION

Many hazards may be present when responding to hazardous materials spills or uncontrolled waste sites. These include oxygen-deficient atmospheres, combustible/explosive atmospheres, toxic atmospheres, and radiation. As outlined in Table 2-7, there are several types of instrumentation available for detecting hazardous atmospheres. This section will discuss in greater detail oxygen monitors, combustible gas indicators (CGIs), and monitors for specific chemicals.

OXYGEN MONITORS

Oxygen monitors are used to evaluate an atmosphere for:

- Oxygen content for respiratory purposes. Normal air contains 20.8% oxygen. Generally, if the oxygen content decreases below 19.5%, it is considered oxygen deficient and special respiratory protection is needed.
- Increased risk of combustion. Generally, concentrations above 25% are considered oxygen enriched and increase the risk of combustion.
- Use of other instruments. Some instruments require sufficient oxygen for operation. For example, CGIs do not give reliable results at oxygen concentrations below 10%. Also, the inherent safety approvals for instruments are for normal atmospheres and not for oxygen-enriched ones.
- The presence of contaminants. A decrease in oxygen content can be due to the

consumption (by combustion or a reaction such as rusting) of oxygen or the displacement of air by a chemical. If it is due to consumption, then the concern is the lack of oxygen. If it is due to displacement, then there is something present that could be flammable or toxic. Because oxygen makes up only 20.8% of air, a 1% drop in oxygen means that about 5% air (air being 1 part oxygen and 4 parts nitrogen) has been displaced. This means that 5% or 50,000 ppm (1% = 10,000 ppm) of “something” could be there.

Most indicators have meters that display the oxygen concentration from 0 to 25%. There are also oxygen monitors available that measure concentrations from 0 to 5 % and from 0 to 100%. The most useful range for hazardous material response is the 0-25 % oxygen content readout because decisions involving air-supplying respirators and the use of CGIS fall into this range.

The oxygen sensor can be on the outside (external) or inside (internal) of the instrument. Internal sensors need a pump-- battery operated or hand-operated-- to draw a sample to it. Units that combine O₂ meters and CGIs into one instrument are available from many manufacturers. Also, flashing and audible alarms can be found on many instruments. These alarms go off at a preset oxygen concentration to alert the users even if they are not watching the meter.

Principle of Operation

FIGURE 1. SCHEMATIC OF OXYGEN SENSOR

Source: *Atmospheric Monitoring for Employee Safety*, BioMarine Industries Inc.

Oxygen monitors use an electrochemical sensor to determine the oxygen concentration in air. A typical sensor consists of two electrodes, a housing containing a basic electrolytic solution, and a semipermeable Teflon® membrane (**Figure 1**).

Oxygen molecules (O₂) diffuse through the membrane into the solution. Reactions between the oxygen, the solution, and the electrodes produce a minute electrical current proportional to the oxygen content. The current passes through an electronic circuit which amplifies the signal. The resulting signal is shown as a needle deflection on a meter or as a digital reading. In some units, air is drawn into the oxygen detector with an aspirator bulb or pump; in other units, the ambient air is allowed to diffuse to the sensor.

Limitations and Considerations

The operation of oxygen monitors depends on the absolute atmospheric pressure. The concentration of atmospheric oxygen is a function of the atmospheric pressure at a given altitude. Whereas the actual percentage of oxygen does not change with altitude, at sea level the weight of the atmosphere above is greater, and more O₂ molecules (and the other components of air) are compressed into a given volume than at higher elevations. As elevation increases, this compression decreases, resulting in fewer air molecules being “squeezed” into a given volume. Consequently, an O₂ indicator calibrated at sea level and operated at an altitude of several thousand feet will falsely indicate an oxygen-deficient atmosphere because

less oxygen is being “pushed” into the sensor. Therefore, it is necessary to calibrate the instrument at the altitude in which it is being used.

The reaction that produces the current in the sensor is nonreversible. Thus, once the sensor is exposed to oxygen, it begins to wear out. The normal life span of a sensor is 6 months to 1 year. Sensors are shipped in sealed packages that have been purged with nitrogen. The packet should not be opened until the sensor is to be used. Storing the sensor in an oxygen absent atmosphere after opening the package can prolong the sensor life, but may not be practical.

High concentrations of carbon dioxide (CO_2) may shorten the useful life of the oxygen sensor. As a general rule, the unit can be used in atmospheres greater than 0.5% CO_2 only with frequent replacing or rejuvenating of the sensor. Lifetime in a normal atmosphere (0.04% CO_2) can be from 6 months to 1 year depending on the manufacturer’s design. The service life of one sensor is 100 days in 1% CO_2 and 50 days in 5% CO_2 .

Strong oxidizing chemicals, like ozone and chlorine, can cause increased readings and indicate high or normal O_2 content when the actual content is normal or even low.

Temperature can affect the response of oxygen indicators. The normal operating range for them is between 32° F and 120° F. Between 0° F and 32° F the response of the unit is slower. Below 0° F the solution may freeze and damage the sensor. High temperature can also shorten the sensor life. The instrument should be calibrated at the temperature at which it will be used.

COMBUSTIBLE GAS INDICATORS

CGIs measure the concentration of a flammable vapor or gas in air, indicating the results as a percentage of the lower explosive limit (LEL) of the calibration gas. The LEL (or LFL - lower flammable limit) of a combustible gas or vapor is the minimum concentration of the material in air which will propagate flame on contact with an ignition source. The upper explosive limit (UEL) is the maximum concentration. Below the LEL there is insufficient fuel to support combustion. Above the UEL, the mixture is too “rich” to support combustion, so ignition is not possible. Concentrations between the LEL and UEL are considered flammable.

CGIs are available in many styles and configurations. The combustible gas sensor can be on the outside (external) or inside (internal) of the instrument. Internal sensors need a battery- or hand-operated pump to draw a sample to it. Many units are “combination meters.” This means they have an O_2 meter and a CGI (and sometimes one or two specific gas indicators) combined in the same instrument. Flashing and audible alarms are options on many units. The alarms go off at a preset concentration to warn the instrument operator of potentially hazardous concentrations. Other options such as longer sampling lines, moisture traps, and dust filters are also available.

Principle of Operation

CGIs use a combustion chamber containing a filament that combusts the flammable gas. To facilitate combustion, the filament is heated or is coated with a catalyst (like platinum or

palladium), or both. The filament is part of a balanced resistor circuit called a Wheatstone bridge (**Figure 2**). The hot filament combusts the gas on the immediate surface of the element, thus raising the temperature of the filament. As the temperature of the filament increases, so does its resistance. This change in resistance causes an imbalance in the Wheatstone bridge. This is measured as the ratio of combustible vapor present compared to the total required to reach the

Figure 2

LEL. For example, if the meter reads 50% (or 0.5, depending upon the readout), this means that 50% of the concentration of combustible gas needed to reach a flammable or combustible situation is present. If the LEL for the gas is 5%, then the meter would be indicating that a 2.5% concentration is present. Thus, the typical meter indicates concentration up to the LEL of the gas (**Figure 3a**).

If a concentration greater than the LEL and lower than the UEL is present, then the meter needle will stay beyond the 100% (1.0) level on the meter (**Figure 3b**). This indicates that the ambient

FIGURE 3 - COMPARISON OF METER READINGS TO COMBUSTIBLE GAS CONCENTRATIONS

atmosphere is readily combustible. When the atmosphere has a gas concentration above the UEL, the meter needle may rise above the 100% (1.0) mark and then return to zero (**Figure 3c**). This occurs because the gas mixture in the combustion cell is too rich to burn. This permits the filament to conduct a current just as if the atmosphere contained no combustibles at all. Some instruments have a lock mechanism that prevents the needle from returning to zero when it has reached 100%. This mechanism must be reset in an atmosphere below the LEL.

Limitations and Considerations

The instruments are intended for use only in normal oxygen atmospheres. Oxygen-deficient atmospheres will produce lowered readings. Also, the safety guards that prevent the combustion source from igniting a flammable atmosphere are not designed to operate in an oxygen-enriched atmosphere.

Organic lead vapors (e.g., leaded gasoline), sulfur compounds, and silicone compounds will foul the filament. Acid gases (e.g., hydrogen chloride and hydrogen fluoride) can corrode the filament. Most units have an optional filter that protects the sensor from leaded vapors.

The response of the instrument is temperature dependent. If the temperature at which the instrument is zeroed differs from the sample temperature, the accuracy of the reading is affected. Hotter temperatures raise the temperature of the filament and produce a higher than actual reading. Cooler temperatures will reduce the reading. The instrument should be calibrated and zeroed at the same temperature that a reading will be taken. Some instruments have a compensating filament (**Figure 2**). This filament is similar to the sensor and is exposed to the same atmosphere, but it does not combust the atmosphere. It compensates for any temperature changes not caused by the combustible gas. There is no differentiation between

petroleum vapors and combustible gases. If the flammability of the combined vapors and gases in an atmosphere is the concern, this is not a problem. However, if the instrument is being used to detect the presence of a released flammable liquid like gasoline in a sewer system where methane may be present, the operator cannot tell whether the reading is the contaminant or the methane. A prefilter can be used to remove the vapors, but it will not remove the methane. Thus, if readings are made with and without the filter, the user can compare the readings and can conclude that differences in the values indicate that a petroleum vapor (i.e., the contaminant) is present.

Relative response is also a concern. If the CGI is used to monitor a gas/vapor that the unit is not calibrated to, it can give inaccurate results. **Figure 4** illustrates the effect of relative response.

TOXIC ATMOSPHERE MONITORS

Along with oxygen concentration and flammable gases or vapors, there is also a concern about chemicals present at toxic concentrations. This usually involves measurements at concentrations lower than what would be indicated by oxygen indicators or CGIs. There is a need to determine whether toxic chemicals are present and to identify them so the environmental concentration can be compared to exposure guidelines. Toxic atmosphere monitoring is performed in order to:

- Identify airborne chemicals and their concentrations
- Evaluate the exposure of workers and the public
- Evaluate the need for and type of personal protective equipment
- Develop controls for exposure in the form of engineered safeguards, work practices, safety plans, and work zones.

Several different groups of instruments can be used for these functions. The following types will be discussed:

- *Specific chemical monitors* are instruments designed to respond to a specific chemical. Common types include instruments that use electrochemical cells or metal-oxide semiconductors (MOS), colorimetric indicators, and mercury detectors.

- **FIGURE 4 - EXAMPLES OF RELATIVE RESPONSE CURVES FOR MSA MODEL 260**

Source: *Portable Gas Indicator, Model 250 and 260, Response Curves*
Mine Safety Appliances Company, Pittsburgh, PA

- *Total vapor survey meters* have detectors (e.g., photoionization detector [PID] or flame ionization detector [FID]) that respond to a variety of chemicals.

- *Gas chromatographs* are used to help identify what chemicals are present in the atmosphere.

SPECIFIC CHEMICAL MONITORS

Electrochemical Cells

Electrochemical cells (**Figure 1**) contain a chemical solution and two or more electrodes. The chemical reacts with the solution or the electrodes. The reaction can be a generation of electrical current or a change in conductivity of the solution. The change in signal is expressed as a needle movement or a digital response on a meter. The selectivity of the sensor depends on the selection of the chemical solution and the electrodes.

In addition to the previously mentioned oxygen monitors (**Figure 1**), there are electrochemical sensors for ammonia, carbon monoxide, carbon dioxide, chlorine, hydrogen chloride, hydrogen cyanide, and hydrogen sulfide. Examples of these instruments are Compur's **Monitox**[®] Personal Monitor Alarms, MDA's **MSTox 8600** series, and National Draeger's **PAC** series of personal monitors.

Limitations and Considerations

Like the oxygen sensor, these electrochemical sensors also can wear out and are affected by temperature and humidity.

Electrochemical cells are also affected by interferences. For example, many of the carbon monoxide sensors will also respond to hydrogen sulfide. In fact, one manufacturer uses the same sensor for both carbon monoxide and hydrogen sulfide detectors. The user must inform the instrument which chemical is being monitored so the readout is in the proper units.

Metal-Oxide Semiconductors

MOS detectors, also called solid-state sensors, consist of a metal-oxide film coating on heated ceramic substrate fused or wrapped around a platinum wire coil. When a gas comes in contact with the metal oxide, it replaces oxygen in the oxide and alters the conductivity of the semiconductor. The change in conductivity can be expressed in a meter readout. The substrate is heated to give a constant baseline as oxygen in the air can combine with the oxide. Selectivity can be determined by selecting specific metal oxides and/or using specific temperatures from the heater to prevent chemicals from reacting.

There are MOS detectors for ammonia, carbon monoxide, hydrogen chloride, hydrogen cyanide, hydrogen sulfide, methyl chloride, nitrogen oxides, and sulfur dioxide. Examples of instruments that use an MOS to detect specific toxic compounds are the Enmet **Tritechtor**[®] and Biosystem's **Model 100** series.

Even though the choice of metal oxide and sensor temperature can make the detector somewhat selective, interferences are a major problem.

Because the sensor reaction is based on presence (or absence) of oxygen in the metal-oxide film, factors that affect oxygen concentration affect meter response. The sensor needs a minimum 14% ambient oxygen for operation. High concentrations can saturate the sensor, causing a slow recovery.

A minimum of 10% humidity is needed for some sensors (check the manufacturer's specifications).

Colorimetric Indicators

Colorimetric indicators use a chemical to react with the contaminant to produce a color change. The chemical can be impregnated on a tape or a badge or put inside a glass tube. The color change can be read by the human eye or by a spectrophotometer to determine the concentration of the contaminant.

The chemicals are not always specific and can be affected by interfering chemicals. Humidity can act as an interference by producing a reaction. Cold temperatures can slow the chemical reaction. Hot temperatures may also cause the chemicals to indicate a reaction.

Examples of colorimetric indicators are the Envirometrics, Inc. **ACT™** cards (badges), MDA Scientific's **7100 Series** (tape), and Draeger detector tubes.

Mercury Detectors

Mercury detectors use either ultraviolet light absorption or a gold film detector. Mercury vapor absorbs a certain wavelength of ultraviolet light. The instrument draws a sample into a chamber and exposes it to the ultraviolet light source. The concentration of mercury vapor is measured by the amount of light absorbed.

Some organic chemicals can absorb the ultraviolet light and act as an interference. Water vapor also absorbs ultraviolet light, but can be adjusted for if the instrument is zeroed in the same humidity as the sample area.

The gold film detector has a gold film as part of a circuit. Mercury reacts with the gold and changes the resistance of the film. The change in resistance is used to determine concentration.

Because most operators do not have a mercury vapor standard, the gold film detector must be factory calibrated. After long exposures or high concentrations, the film needs to be "cleaned." This requires heating the film and using an AC power source.

An example of an ultraviolet absorption instrument is the Bacharach **Model MV-2**. An example of a gold film instrument is the Jerome Instruments **Model 411**.

CONCLUSION

Many hazards can be present at a hazardous materials operation. Instruments are available for

determining the presence of hazardous situations like combustible atmospheres, oxygen-deficient atmospheres, and toxic atmospheres. The instruments discussed in this section can only identify certain hazardous situations and should be selected and used accordingly.

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CHAPTER 3

3.0 PROTECTIVE CLOTHING AND EQUIPMENT

3.1 OBJECTIVE

To provide general information on selecting and using appropriate personal protective clothing and equipment.

3.2 SELECTION OF PERSONAL PROTECTIVE CLOTHING AND EQUIPMENT (PPE)

Proper selection of PPE requires a thorough understanding of the hazards to be faced:

- Chemical - inhalation, skin contact
- Mechanical - falling objects, moving parts
- Physical - noise, radiation
- Thermal - heat, cold
- Electrical

General Precautions

- Use the correct type of equipment needed.
- Use only properly fitting personal protective equipment.

Head Protection

- Essential where there are overhead hazards (platforms, scaffolding, piping)
- American National Standards Institute (ANSI) standard: impact of 400 foot-pounds and insulation against 2,200 volts.
- Adjust suspension harness so there is 3 cm (1") clearance between hat and top of head.
- Can be equipped with insulation and chin strap.
- Store properly.

Eye and Face Protection

- Use whenever there is danger of flying or falling particles or chemical splashes.
- Use eye and face protection which meets ANSI Z87.1-1981 standards and OSHA requirements.

- Ordinary prescription glasses do not meet standards.
- Always carry and use your own eye protection.
- Side shields, goggles and face shields may be necessary.
- Contact lenses should not be worn at sites where eye and face protection is necessary:
 - May complicate first aid efforts.
 - May absorb gases and vapors from the air and aggravate chemical injury.
 - OSHA prohibits use of contact lenses when respirators are worn.

Foot Protection

Make selection based on hazard to be encountered:

- Impact
- Penetration
- Chemicals
- Ankle twists and sprains
- Slippery surfaces
- Cold
- Heat
- Static electricity

Impact

- Use steel-toed footwear where heavy objects may drop on the foot (ANSI Z41.1).
- Metatarsal guards may be required at the site.

Penetration

- Where soles may be penetrated, wear safety boots with reinforced soles.

Chemicals

- Select footwear (boots, pullover boots, shoe covers) based on ability to resist penetration or permeation by the chemicals.
- Possible materials: neoprene, PVC, butyl rubber, natural rubber.

- Do not wear leather footwear where contamination may occur.

Ankle Twists and Sprains

- Wear high-top industrial work boots where there are hazardous walking/working surfaces.

Slippery Surfaces

- Slips, trips and falls are most frequent and most disabling.
- Select footwear with hazard in mind - design and material of sole is important.

Static Electricity

- Rubber-soled shoes increase the hazard.
- Use special conducting shoes or other static diffusing devices.

Hearing Protection

- Long-term exposure can cause permanent loss of hearing (see Figure 3-1).
- Shorter exposures may result in temporary loss.

- If conversation is difficult at a distance of three feet, hearing protection should be used.
- **Noise Reduction Rating (NRR):** ability of hearing protector to reduce sound levels - NRR increases as ability to protect increases (See Table 3-1).
- Choose proper hearing protector for the work environment.
- Be aware of potential contamination of hearing protection.

Figure 3-1. The Ear

TABLE 3-1. TYPICAL NOISE REDUCTION RATINGS (NRRs) FOR COMMON HEARING PROTECTION DEVICES

<u>Type of Hearing Protection Device</u>	<u>Range of NRRs</u>
Premolded earplugs (including flanged and conical models)	16 to 27
Custom-molded earplugs	11 to 31
User-molded earplugs	16 to 26
Self-molding earplugs (expandable foam)	29 to 32

Self-molding earplugs (glass fiber)	22 to 27
Ear muffs (over the head)	19 to 29

Source: NIOSH Compendium of Hearing Protection Devices, 1984.

Hand Protection

- Gloves should be selected based on the probability of:
 - abrasions, bruises, lacerations, splinters, etc.
 - chilling, freezing, or burns
 - chemical and biological contaminants
 - electrical shock
- Refer to the *Guidelines for the Selection of Chemical Protective Clothing* (EPA Regional Health and Safety Offices).
- Liquid-proof gloves are not necessarily permeation resistant.
- A variety of gloves may be necessary to provide proper protection (wear durable over impermeable but delicate).
- See Table 3-2 for information on the physical characteristics of protective materials.
- Have extra gloves available during field activities.

TABLE 3-2. PHYSICAL CHARACTERISTICS OF PROTECTIVE MATERIALS*

Puncture Material Resistance	Tear Resistance	Abrasion Relative Resistance Cost	Cut Resistance	Flexibility	Heat Resistance	Ozone Resistance
Butyl Rubber (Butyl) G G	High	F	G	G	E	E
Chlorinated Polyethylene (CPE) G G	Low	E	G	G	G	E
Natural Rubber E E	Medium	E	E	E	F	P
Nitrile-Butadiene Rubber (NBR) E G	Medium	E	E	E	G	F
Neoprene G G	Medium	E	E	G	G	E

Nitrile Rubber (Nitrile)	E	E	E	G	F
E G Medium					
Nitrile Rubber & Polyvinyl Chloride (Nitrile & PVC)	G	G	G	F	E
G G Medium					
Polyethylene	F	F	G	F	F
P F Low					
Polyurethane	E	G	E	G	G
G G High					
Polyvinyl Alcohol (PVA)	F	F	P	G	E
F G Very High					
Polyvinyl Chloride (PVC)	G	P	F	P	E
G G Low					
Styrene-Butadiene Rubber (SBR)	E	G	G	G	F
F F Low					
Viton	G	G	G	G	E
G G Very High					

*Ratings are subject to variation depending on formulation, thickness, and whether the material is supported by fabric.

E-excellent; G-good; F-fair; P-poor

Skin and Body Protection

- Select clothing for resistance to chemical degradation and permeation, and heat resistance.
- No one suit will provide appropriate protection in all situations.
- A variety of protective garments are available.
- Materials are not intended for prolonged contact with concentrated chemicals; always have extra clothing at the site.
- Do not use synthetic fabric suits when contact with hot surfaces is possible.
- See Appendices 3-A and 3-B for information regarding protective clothing and materials.

3.3 LEVELS OF PROTECTION

To aid in selecting PPE, EPA has developed a protocol consisting of four levels of protection. Each level provides a given degree of protection to the skin and respiratory system (See Table 3-3).

Considerations

- Type, measured concentration, and toxicity of the chemical substance in the ambient atmosphere.
- Potential for exposure to airborne materials, liquid splashes, or other materials.

Reasons for Upgrading

- Known or suspected presence of dermal hazard.
- Occurrence or likely occurrence of gas or vapor emission.
- Change in work task.
- Personal request.

Reasons for Downgrading

- New information regarding hazard.
- Change in site conditions.
- Change in work task.

TABLE 3-3. LEVEL OF PROTECTION

Level of Protection

Equipment

Protection Provided

Should Be Used When

Limiting Criteria

A

RECOMMENDED:

- Pressure-demand, full-facepiece SCBA or pressure-demand supplied-air respirator with escape SCBA.
- Fully-encapsulating, chemical-resistant suit.
- Inner chemical-resistant gloves.
- Chemical-resistant safety boots/shoes.
- Two-way radio communications (intrinsically safe).

OPTIONAL:

- Cooling unit
- Coveralls
- Long cotton underwear
- Hard hat
- Disposable gloves and boot covers

The highest available level of respiratory, skin, and eye protection.

The chemical substance has been identified and requires the highest level of protection for skin, eyes and the respiratory system based on either:

- measured (or potential for) high concentration of atmospheric vapors, gases, or particulates or
- site operations and work functions involving a high potential for splash, immersion, or exposure to unexpected vapors, gases, or particulates of materials that are harmful to skin or capable of being absorbed through the intact skin.

Substance with a high degree of hazard to the skin are known or suspected to be present, and skin contact is possible.

Operations must be conducted in confined, poorly ventilated areas until the absence of conditions requiring Level A protection is determined.

Direct reading field instruments indicate high levels of unidentified vapors and gases in the air.
Fully-encapsulating suit material must be compatible with the substance involved.

TABLE 3-3 (continued)

Level of Protection
Equipment
Protection Provided
Should Be Used When
Limiting Criteria

B

RECOMMENDED:

- Pressure-demand, full-facepiece SCBA or pressure-demand supplied air respirator with escape SCBA.
- Chemical-resistant clothing (coveralls and long-sleeved jacket; hooded, one- or two-piece chemical splash suit; disposable chemical-resistant one-piece suit).
- Inner and outer chemical-resistant gloves.
- Chemical resistant safety boots/shoes.
- Hard hat.
- Two-way radio communications (intrinsically safe).

OPTIONAL:

- Coveralls
- Disposable boot covers
- Face shield
- Long cotton underwear

The same level of respiratory protection as Level A but less skin protection.

It is the minimum level recommended for initial site entries until the hazards have been further identified.

The type and atmospheric concentration of substances have been identified and require a high level of respiratory protection, but less skin protection. This involves atmospheres:

- with IDLH concentrations of specific substances that do not represent a severe skin hazard; or
- that do not meet the criteria for use of air-purifying respirators.

Atmosphere contains less than 19.5 percent oxygen.

- Presence of incompletely identified vapors or gases is indicated by direct-reading organic vapor detection instrument, but vapors and gases are not suspected of containing high levels of chemicals harmful to skin or capable of being absorbed through the intact skin.
- Use only when the vapor or gases present are not suspected of containing high concentrations of chemicals that are harmful to skin or capable of being absorbed through the intact skin.
- Use only when it is highly unlikely that the work being done will generate either high concentrations of vapors, gases or particulates or splashes of material that will affect exposed skin.

TABLE 3-3 (continued)

Level of Protection
Equipment
Protection Provided
Should Be Used When
Limiting Criteria

C
RECOMMENDED:

- Full-facepiece, air-purifying, canister-equipped respirator.
- Chemical-resistant clothing (overalls and long-sleeved jacket; hooded, one- or two-piece chemical splash suit; disposable chemical-resistant one-piece suit).
- Inner and outer chemical-resistant gloves.
- Chemical-resistant safety boots/shoes.
- Hard hat.
- Two-way radio communications (intrinsically safe).

OPTIONAL:

- Coveralls
 - Disposable boot covers
 - Face shield
 - Escape mask
 - Long cotton underwear
- The same level of skin protection as Level B, but a lower level of respiratory protection.
- The atmospheric contaminants, liquid splashes, or other direct contact will not adversely affect any exposed skin.
 - The types of air contaminants have been identified, concentrations measured, and a canister is available that can remove the contaminant.
 - All criteria for the use of air-purifying respirators are met.
 - Atmospheric concentration of chemicals must not exceed IDLH levels.
 - The atmosphere must contain at least 19.5 percent oxygen.

TABLE 3-3 (continued)

Level of Protection
Equipment
Protection Provided
Should Be Used When
Limiting Criteria

D
RECOMMENDED:

- Coveralls
- Safety boots/shoes
- Safety glasses or chemical splash goggles
- Hard hat

OPTIONAL:

- Gloves
 - Escape mask
 - Face shield
- No respiratory protection. Minimal skin protection.
- The atmosphere contains no known hazard.
 - Work functions preclude splashes, immersion, or the potential for unexpected inhalation

or contact with hazardous levels of any chemicals.

- This level should not be worn in highly contaminated areas.
- The atmosphere must contain at least 19.5 percent oxygen.

Adapted from: NIOSH/OSHA/USCG/EPA: Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, 1985.

3.4 CONTROLLING THE TRANSFER OF CONTAMINANTS

Improper use or handling of materials can unintentionally result in transfer of contaminants to unintended objects. Proper preparation will minimize the potential for such contamination.

Planning

- Disposable equipment
- Onsite decontamination
- Method of decontamination
- Disposal
- Appropriate supplies

Preventing Transfer of Contaminants

- Minimize surfaces touched.
- Avoid walking on or through chemical spills.
- Wrap contaminated equipment and containers before placing them on a clean surface.
- Control personal habits which may transfer contaminants to clothing or exposed parts of body.
- Remove protective clothing and discard properly.
- Use disposable equipment and discard on site.
- Decontaminate nondisposable equipment immediately after use or package properly for later decontamination.

3.5 DECONTAMINATION

Contamination may occur even though protective clothing and respirators are used and good work practices are followed. To prevent transfer of contaminants into clean areas, decontamination must be performed. This consists of physically removing contaminants or changing their chemical nature. Use of soap and water is often sufficient for proper decontamination.

- Refer to the NIOSH/OSHA/USCG/EPA *Occupational Safety and Health Guidance Manual for Hazardous Waste Sites*, 1985, or the EPA *Standard Operating Safety Guides*.

- Use large, thick, plastic bags for the disposal of contaminated disposable materials.
- Set up an area onsite for the decontamination of sampling equipment, sample containers, and their carrying containers.
- Wash exposed areas prior to eating, drinking, or using tobacco products with soap and water or premoistened, disposable towelettes.

3.6 DONNING AND DOFFING PROTECTIVE CLOTHING

Achieving the complete benefits of protective clothing depends on the techniques used for donning and doffing the clothing. In general, care must be taken to avoid tearing or puncturing the materials, and to avoid contaminating the inside of the garments.

Helpful Hints

- Pull pants of protective clothing down over the boots and tape in place.
- Tape gloves to sleeves of protective clothing in similar fashion.
- Have an assistant help when you are donning or doffing protective clothing.
- Store protective clothing where it will not become contaminated.
- See Appendix 3-C for specific donning and doffing procedures.

3.7 STORAGE OF EQUIPMENT

Proper storage can result in:

- longer life;
- reduced maintenance;
- increased availability of critical gear;
- minimization of cross-contamination; and
- prevention of punctures and tears.

APPENDIX 3-A

PERFORMANCE REQUIREMENTS OF PROTECTIVE CLOTHING

Clothing Section

Select personal protective clothing which will provide the best possible protection against the chemicals and environment to which you will be exposed.

Important characteristics to consider:

- Strength and durability - generally proportional to thickness; however, increased durability

generally reduces flexibility.

- Thermal resistance - behavior in hot/cold environments? - melting?
- Ability to be cleaned, decontaminated, or protected from contamination.
- Resistance of protective clothing to chemical damage or degradation, mechanical penetration, and permeation through the intact material.

Resistance to Degradation by Chemicals

A great deal of information concerning the chemical resistance of materials from which protective gloves and clothing are made can be obtained.

Resistance to Penetration by Chemicals

- Select personal protective clothing with care; porous materials, tears, punctures, stitched seams, button holes and loose openings can allow penetration.
- Store, transport and handle gloves and protective clothing with care at all times.
- Inspect personal protective clothing for holes before use.
- Seal openings between garments, gloves and boots with adhesive tape that will resist the hazardous material you expect to encounter.

Resistance to Permeation by Chemicals

- Gases, liquids and some solids can diffuse through materials used to make protective gloves and clothing.
- Permeation can occur without degradation or damage to the protective material.
- No protective material will resist permeation by all chemicals.
- Reduce permeation by:
 - minimizing concentrations in contact with protective materials;
 - using thicker materials; and
 - avoiding prolonged exposure or contact with chemicals.

APPENDIX 3-B

PROTECTIVE MATERIALS

Fabrics

- **Tyvek:** non-woven fabric; resists tears, punctures and abrasion; relatively inexpensive; used for disposable garments; resists buildup of static electricity (unless laundered); melting point: 135°C (275°F).
- **Nomex:** woven fabric of polyamide fibers; very durable and acid-resistant; flame-resistant, but not noncombustible; allows passage of gas, vapor and steam.

Elastomers

Are natural or synthetic polymeric materials that exhibit good elasticity and varying degrees of resistance to chemical degradation and permeation.

- **Polyethylene:** inert but permeable material that will absorb organic solvents; sometimes used to coat Tyvek garments to provide resistance to acids, bases and salts.
- **Polyvinyl chloride (PVC):** resistant to acids, but somewhat permeable and retentive of contaminant; coating for fully-encapsulating suits made of Nomex.
- **Neoprene:** better general protection than PVC; retains contaminants; many respirator facepieces and breathing hoses.
- **Chlorinated polyethylene (CPE or Choropel):** resists degradation by many chemicals; permeation resistance unknown; splash suits and fully-encapsulating suits.
- **Butyl Rubber:** highly resistant to permeation by gases; does not resist halogenated hydrocarbons and petroleum compounds; does not retain contaminants; boots, gloves, splashsuits, aprons and fully-encapsulating suits.
- **Viton:** fluoroelastomer with greater resistance to degradation and permeation than neoprene and butyl rubber; does not protect against some chemicals like ketones and aldehydes; does not retain contaminants; fully-encapsulating suits.
- **Natural rubber:** resists degradation by alcohols and caustics; used for boots and gloves.
- **Milled nitrile:**
Resists petroleum products; boots and gloves.
- **Polyvinyl alcohol (PVA):** soluble in water but protects against aromatic and chlorinated hydrocarbons.

For additional information consult EPA's *Guidelines for the Selection of Chemical Protective Clothing*, 1987.

APPENDIX 3-C

PROCEDURES FOR DONNING AND DOFFING PERSONAL PROTECTIVE CLOTHING

Using Gloves

Gloves

- Trim fingernails and remove jewelry which may puncture material.
- Use powdered gloves if possible.

- Use several layers of differing gloves if necessary.

Removing Gloves

- Loosen both gloves by pulling lightly on each fingertip of the gloves.
- Do not touch your skin with the outer surface of either glove.
- Remove the first glove either by pulling on the fingertips or by grasping it just below the cuff on the palm side and rolling the glove off the fingers.
- Remove the second glove by inserting the ungloved fingers inside the cuff on the palm side without touching the outside of the glove, and pushing or rolling the glove off the fingers.

Using Boots

Boots

- Before use, be sure shoes cannot puncture overboots.
- Use layers of boots of differing capabilities if necessary.

Removing Boots

- Wear gloves unless boots are very loose.
- Loosen boots by pulling them lightly with the gloved hand.
- Do not allow outside of boot to contact bare skin.
- Remove first boot by pulling it off the foot with a gloved hand or a bootjack, or by inserting the ungloved fingers inside the boot and pushing it off without touching the outside of the boot.
- Remove second boot in the same fashion.

Using and Removing Full Body Suits

Safe use of full protective equipment requires a team of persons who are physically fit and trained and practiced in the use of self-contained breathing apparatus and use of the complete suits. Assistants must be prepared to:

- Carry out emergency rescue if necessary.
- Assist the wearers into the breathing apparatus and the suits.
- Decontaminate the outside of the suit before it is removed.
- Assist the wearers in removing the suits (normal and emergency removals).

Donning the Suit

- Thoroughly inspect the suit for holes, rips, malfunctioning closures, cracked masks or other deficiencies.

- Wear a minimum of clothing beneath suit (cotton).

- Use talcum powder as necessary.

Doffing the Suit

- Remove any extraneous or disposable clothing, boot covers, or gloves.
- Have assistant perform the following:
 - Loosen and remove the steel-toe and shank boots.
 - Open front of suit to allow access to SCBA regulator. (Leave breathing hose attached as long as there is sufficient pressure.)
 - Open suit completely and lift the hood over the head of the wearer; rest it on top of the SCBA tank.
- Remove arms, one at a time, from suit. Once arms are free, have assistant lift suit up and away from the SCBA backpack, avoiding any contact between the outside surface of the suit and the wearer's body, and lay the suit out flat behind the wearer. Leave internal gloves on.
- While sitting, remove both legs from the suit.
- After suit is removed, remove internal gloves by rolling them off the hand, and turning them inside out.
- Proceed to the clean area and follow procedure for doffing SCBA.
- Remove internal clothing and thoroughly cleanse body.

CHAPTER 4

4.0 RESPIRATORY PROTECTION

4.1 OBJECTIVE

To provide basic information on the selection, use and maintenance of respiratory protective devices so that they may be used in a safe and effective manner.

4.2 RECOGNITION OF RESPIRATORY HAZARDS

Respiratory hazards may be encountered during any field activity. Respiratory protection is needed if personnel must enter any area in which there may be either a deficiency of oxygen or a high concentration of toxic chemicals in the air. In such atmospheres, life or health may depend on using respiratory equipment which can provide a supply of clean breathing air.

Hazard Locations

- Spill scenes
- Discharge or emission sites
- Mines
- Industrial plants
- Hazardous waste sites
- Confined spaces

General Considerations

- Do not rely on workaday respiratory use policy.
- Assume the worst conditions.
- Three basic categories of hazards: oxygen deficiency, aerosols gases and vapors

Oxygen Deficiency

- Causes
 - displacement
 - oxidation
- Minor to fatal effects (see Table 4-1)
- <19.5% oxygen at sea level (OSHA)

Aerosols

- Fine particulate (solid or liquid) suspended in air
- Physical classifications
 - spray
 - fume
 - fog
 - smoke
 - smog

TABLE 4-1. PHYSIOLOGICAL EFFECTS OF OXYGEN DEFICIENCY

Oxygen Volume at Sea Level (%)	Effects
12 to 16	- Breathing volume and heart rate increase.
- Attention and coordination impaired.	
10 to 14	- Loss of peripheral vision.
- Poor coordination.	
- Rapid fatigue with exertion.	
- Emotional upsets and faulty judgment.	
- Respiration disturbed.	
6 to 10	- Nausea and vomiting.
- Unable to move freely.	
- Possible loss of consciousness.	
Below 6	- Convulsions
- Gasping respiration immediately prior to cessation of breathing which is followed quickly by death.	

Aerosols (cont.)

- Physiological classification
 - nuisance
 - inert pulmonary reaction
 - lung fibrosis
 - irritation
 - systemic poison
 - allergen
 - carcinogen

Gaseous

Contaminants

- Chemical classification
 - acidic
 - alkaline
 - organic
 - organometallic
 - hydrides
 - inert
- Physiological classification
 - irritant
 - asphyxiant
 - anesthetic
 - systemic poison
 - allergen
 - carcinogen

4.3 TYPES OF RESPIRATORS

Basic Types

- Air-purifying
- Atmosphere-supplying

Facepieces

- Tight-fitting or loose-fitting

Tight-fitting

- Quarter mask
- Half mask
- Full facepiece

Loose-fitting

- Hoods
- Helmets
- Suits
- Blouses

Air-Purifying Respirators

- Consist of face-piece and air-purifying device.
- Can remove specific airborne contaminants by
 - filtration;
 - absorption;
 - adsorption; or
 - chemical reaction.
- Are approved for use only in atmospheres of certain concentrations of chemicals (see cartridges or canisters).
- Usually operate in negative-pressure mode (exception: powered air-purifying respirators).

Precautions

- Cartridges in two-cartridge respirators must be of same type.

- Combination cartridges may be used for protection against more than one type of chemical.
- Use air-purifying respirators when:
 - identify and concentration of contaminant are known;
 - oxygen in air is at least 19.5%;
 - contaminant has adequate warning properties;
 - approved canisters or cartridges for the contaminant and concentration are available;
 - the Immediately Dangerous to Life or Health (IDLH) concentration is not exceeded.

Styles

- See Table 4-3 for styles of respirators.
- See Table 4-2 for the advantages/disadvantages of air-purifying respirators.

TABLE 4-2. RELATIVE ADVANTAGES AND DISADVANTAGES OF AIR-PURIFYING RESPIRATORS

Air-Purifying

Type of Respirator	Advantages	Disadvantages
Air-Purifying Respirator (including powered air-purifying respirators (PAPRs))		•Enhanced mobility
	•Lighter in weight than an SCBA. Generally weighs 2 pounds (1 kg) or less (except for PAPRs).	•Cannot be used in IDLH or oxygen-deficient atmospheres (less than 19.5 percent oxygen at sea level).
	•Limited duration of protection. May be hard to gauge safe operating time in field conditions.	
	•Only protects against specific chemicals and up to specific concentrations.	
	•Use requires monitoring of contaminant and oxygen levels.	
	•Can only be used (1) against gas and vapor contaminants with adequate warning properties, or (2) for specific gases or vapors provided that the service life is known and a safety factor is applied, or if the unit has an ESLI (end-of-service-life indicator).	

Source: NIOSH/OSHA/USCG/EPA: Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, 1985.

TABLE 4-3. RESPIRATOR STYLES

Air-Purifying Unit				
Facepiece				
Twin Cartridges				
PAPR at Waist				
Canister	Chin-mounted			
Canister	Harness-mounted			
Half-mask	X	X		
Full-face mask	X	X	X	X
Helmet		X		

Atmosphere Supplying Respirators

- Consist of facepiece (loose or tight-fitting) and device which provides clean respirable air.
- Two basic types:
 - self-contained breathing apparatus (SCBA)
 - supplied air respirator (SAR)

SCBA

- Carried by wearer
- Consists of:
 - facepiece
 - hose
 - regulator
 - air source
- Protects against most levels and types of contaminants.
- Duration of use limited by amount of air carried and breathing rate.
- Increases likelihood of heat stress and fatigue due to weight.
- Impairs movement.
- See Table 4-4 for advantages/disadvantages of SCBAs.

SAR

- Also known as air-line respirators.
- Supply air to facepiece via a supply line from a stationary source.
- Source may be onsite compressor or compressed air cylinders.
- Available in positive- and negative-pressure modes.

Precautions

- Should not be used in IDLH atmospheres unless equipped with escape SCBA.
- Use of compressors limited by quality of ambient air.
- Couplings must be incompatible with outlets of other gas systems used onsite.
- See Table 4-4 for advantages/disadvantages of atmosphere-supplying respirators.

TABLE 4-4. RELATIVE ADVANTAGES AND DISADVANTAGES OF ATMOSPHERE-SUPPLYING RESPIRATORY PROTECTIVE EQUIPMENT

Type of Respirator

Advantages

Disadvantages

Self-Contained Breathing Apparatus (SCBA)

- Provides the highest available level of protection against airborne contaminants and oxygen deficiency.
- Provides the highest available level of protection under strenuous work conditions.
- Bulky, heavy (up to 35 pounds).
- Finite air supply limits work duration.
- May impair movement in confined spaces.

Positive Pressure Supplied-Air Respirator (SAR) (also called air-line respirator)

- Enables longer work periods than an SCBA.
- Less bulky and heavy than a SCBA. SAR equipment weighs less than 5 pounds (or around 15 pounds if escape SCBA protection is included).

- Protects against most airborne contaminants.
- Not approved for use in atmospheres immediately dangerous to life or health (IDLH) or in oxygen-deficient atmospheres unless equipped with an emergency egress unit such as an escape-only SCBA that can provide immediate emergency respiratory protection in case of air-line failure.
- Impairs mobility.
- MSHA/NIOSH certification limits hose length to 300 feet (90 meters).
- As the length of the hose is increased, the minimum approved air flow may not be delivered at the facepiece.
- Air line is vulnerable to damage, chemical contamination, and degradation. Decontamination of hoses may be difficult.
- Worker must retrace steps to leave work area.
- Requires supervision/monitoring of the air supply line.

Source: NIOSH/OSHA/USCG/EPA: Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, 1985.

Combined SCBA/SARs

- Can operate in either SCBA or SAR mode.
 - CBA - entry and exit.
 - SAR - extended work in contaminated area

Respirator Certification

- NIOSH/MSHA
- Respirators and components are certified as a unit; interchanging parts voids certification.

Limitations

- Air-purifying filters and cartridges approved for only certain materials and conditions of use (organic vapor cartridge - adequate warning properties and at least 19.5% O₂).

Assigned Protection Factor (APF)

- Each type of respirator (half-mask, PAPR, etc.) is assigned an APF.
- $APF = \text{Outside Concentration} / \text{Inside Concentration}$.

Example - respirator with APF of 100

If outside concentration = 200 ppm, what is concentration inside facepiece?

$$100 = 200 \text{ ppm} / x \text{ ppm}$$

$$x = 2 \text{ ppm}$$

- Can use APF and PEL or TLV to determine maximum concentration of contaminant in which respirator can be used.

Maximum concentration (ppm) = APF x Allowable Exposure Limit

Example - Air-purifying, half-mask respirator: APF = 10.

Contaminant: TLV = 20 ppm

Maximum Concentration = APF x TLV

x = 10 x 20

x = 200 ppm

- See Table 4-5 for assigned protection factors.

TABLE 4-5. RESPIRATOR PROTECTION FACTORS

Assigned Protection Factor	Type of Respirator	Contaminant	Particulate	Gas/Vapor	Combination
10		APR/half-mask	X	X	X
		APR/full-face	X (any type)		X (any type
	particulate filter)				
		SAR/half-mask/negative			X X
25		PAPR/hood or helmet	X	X	X
		SAR/hood or helmet/			
	continuous flow	X	X		
50		APR/full-face	X (HEPA)	X	X (HEPA)
		PAPR/tight-fitting	X (HEPA)	X	X (HEPA)
		SAR/full-face/			
negative		X	X	X	
		SAR/tight-fitting/			
	continuous flow		X	X	
		SCBA/full-face/negative		X	X X
1000		SAR/half-mask/positive		X	X X
2000		SAR/full-face/positive	X	X	X
10,000		SCBA/full-face/			
positive		X	X	X	
		SCBA/full-face/			
	positive/				
	auxiliary positive	X	X	X	

4.4 RESPIRATOR SELECTION

Respirator selection is a complex process that should be performed only by a trained industrial

hygienist familiar with the actual work environment and job tasks to be performed.

General Considerations

- Nature of hazardous operation, process or condition
- Contaminant, type of hazard, concentration, effects on body
- Activities to be conducted
- Time protection needed
- Escape time
- Available respiratory protection equipment
- Service life of cartridges/canisters

Contaminant Considerations

- Physical, chemical, toxicological properties
- Odor threshold
- REL, TLV, PEL
- IDLH concentration
- Eye irritation potential

Respiratory Hazards

- Oxygen deficiency
- Flammable atmosphere
- Toxic atmospheres

Oxygen Deficiency

- SCBA/pressure-demand
- SAR/auxiliary SCBA

Flammable Atmospheres

- General Policy: do not enter if >25 % of LEL.
- SCBA/pressure-demand

Toxic Atmospheres

- IDLH - SCBA/pressure-demand
- Above PELs but below IDLH - APR or SAR
- Below PEL - none required

4.5 RESPIRATOR USE

Respirator Policy

- Provide appropriate respiratory protection devices for agency employees.
- Require use of devices when necessary to protect health:
 - high potential for sudden release, or actual release of toxic gases/vapors;
 - hazardous environments or locations (spill sites);
 - confined spaces;
 - engineering controls not feasible.
- Allow employees to wear respiratory protection even when concentrations are not expected to harm health and others are not affected.
- Keep hazardous conditions under surveillance.
- Keep employee exposure or stress at safe levels.

- Require standby personnel at IDLH atmospheres.
- Require written Standard Operation Procedures (SOPs) for selection and use of respiratory protective equipment.

Respirator Program Requirements

- Written program (SOPs)
- Respirator selection
- Training
- Respirator assignment
- Cleaning
- Storage
- Inspection and maintenance
- Surveillance
- Program evaluation
- Physical examination

4.6 SPECIAL CONSIDERATIONS

- Facial hair
- Eye glasses
- Contact lenses
- Facial deformities
- Communication

4.7 RESPIRATOR FIT TESTING

- Required for negative pressure air-purifying respirators.

Varieties

- Two types:
 - qualitative
 - quantitative
- See Table 4-6 for advantages/disadvantages of qualitative and quantitative fit testing.

Fit Checks

- Negative Pressure Test - tests exhalation valve and facepiece seals.
- Positive Pressure Test - tests inhalation valves and facepiece seals.

Qualitative Fit Testing

- Determine sensitivity to challenge material:
 - banana oil (isoamyl acetate)
 - saccharin

- irritant smoke (stannic chloride)
- Select respirator.
- Conduct positive/negative fit check.
- Enter test chamber.
- Introduce challenge material.
- Perform test exercises (minimum of one minute each):
 - breathe normally
 - breathe deeply
 - turn head side to side
 - nod head up and down
 - talk aloud several minutes
 - jog in place
 - breathe normally
- If challenge material is not detected, subject has passed test (PF = 10).

Quantitative Fit Testing

- Conduct qualitative fit test.
- Follow instructions for quantitative fit testing equipment used (fit test chamber, “Portacount”).
- Perform test exercises.
- Determine fit factor.

TABLE 4-6. ADVANTAGES AND DISADVANTAGES OF QUALITATIVE AND QUANTITATIVE FIT TESTING

Fit Test	Advantages	Disadvantages
Qualitative	Fast	
Inexpensive		
Simple		
Easily performed in the field	Relies on wearer’s subjective response (may not be reliable).	
Quantitative	Does not rely on wearer’s subjective response	
(Is recommended when the respirator is used in highly toxic atmospheres or those immediately dangerous to life and health). Requires qualified personnel and equipment.		

Testing cannot be done on the respirator which will be used.

